CYTOGENETICAL AND MORPHOLOGICAL STUDY OF ISRAELI AND TURKISH WILD EMMER (TRITICUM TURGIDUM L. EM. VAR. DICOCCOIDES /KÖRN/ BOWDEN) COLLECTIONS AND THEIR RELATION TO OTHER TETRAPLOID WHEATS

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CHAPTER I

INTRODUCTION

Wheat is the world's most widely cultivated crop. It is also one of the few crops in which intensive research on systematics, cytology, and genetics has been conducted. Genome analysis was first worked out in wheat and later extended to other crops. The distribution, origin, and evolution of wheat has been studied in some detail during the last fifty years and the interrelationships of various groups of wheat are fairly well understood. There are several polyploid species involved in the construction of an elaborate interconnecting polyploid superstructure. The polyploids form clusters of related species. In each species cluster it has been demonstrated that all species have one unmodified genome in common, but differ from one another by the addition of one or more modified genomes (41). The common genome in each case buffers the genotype so that rather wide crosses are possible. Introgression between species is common at polyploid levels where great stores of genetic variability can be accumulated (9). The achievement of a balanced polyploid organization through genic control of meiotic chromosome pairing is one of the major steps of wheat evolution (25).

When the evolutionary history of wheat is considered in more detail, however, some gaps in our knowledge are evident. Controversy still persists in regard to the genome constitution and relationships of certain tetraploid wheat groups. Tetraploid wheats were first given the genome formula AABB (15). In 1934 Lilienfeld and Kihara (18) assigned the genome formula AAGG to the tetraploid, T. timopheevi. The source of the origin of the G genome was not known. Later the G genome was thought to be closer to the B genome and was designated variously as β (beta), B and B^t (16, 17, 26, 37, 38, 7). Sachs (26) suggested that probably all the tetraploid wheat species including T. dicoccoides and T. timopheevi originated from a common 28 chromosome prototype. Harlan and Zohary (11) divided T. dicoccoides into two races, Palestine and Turkish-Iraqi, and suggested that modern tetraploid wheats stemmed from the Palestine race, while the other Turkish-Iraqi race contributed only to the T. timopheevi complex.

In the previous studies very few collections of T. dicoccoides had been analyzed. Detailed information regarding the range of morphological and cytogenetic variation within T. dicoccoides is not available. The present study was initiated in the belief that a biosystematic study with wild emmer and other tetraploid wheat collections would provide much needed information on the origin of cultivated tetraploid wheats and their phylogenetic affinities to the wild relatives. It also appeared desirable to investigate the basis of the suggested division of T. dicoccoides into Palestine and Turkish-Iraqi races and to study the relationship of these races with other tetraploid wheats. Another objective was to learn more about the origin and genome constitution of T. timopheevi.

The classification of Bowden (3) has been followed in this thesis. Except for quoting the work of others, the following terminology has been used: T. turgidum L. em. var. timopheevi (Zhuk) Bowden is designated as timopheevi; T. turgidum L. em. var. dicoccoides (Körn) Bowden is designated as dicoccoides; T. turgidum L. em. cultivar dicoccon (Schrank) Bowden is designated as dicoccon; T. turgidum L. em. cultivar turgidum (L) Bowden is written as turgidum and T. turgidum L. em. cultivar carthlicum (Nevski) Bowden is written as carthlicum.

CHAPTER II

REVIEW OF LITERATURE

Distribution

According to Aaronsohn (1), Körnicke in 1873 discovered a portion of an ear of a previously unreported species of Triticum among the specimens of a Hordeum spontaneum collection in the National Herbarium at Vienna. In 1889 Körnicke named it T. vulgare, vill. var. dicoccoides, considering it closely allied to emmer and the prototype of most of the cultivated wheats. This collection had been made in 1855 by Theodar Kotschy at Rosheyya on the northwestern side of Mount Hermon. The wild emmer (dicoccoides) plants were rediscovered by Aaronsohn in 1906 growing wild at Rosh Pinar at the foot of Jebel Safed in Syria. Later, Vavilov (36) reported the presence of dicoccoides in Palestine, Syria, and Armenia and Georgia of the U.S.S.R.

Zohary and Brick (42) described the distribution of wild emmer in Syrio-Palestine region and studied the ecological conditions in which it grows. Wild emmer was found growing in Israel from sea level to 600 m elevation and where the annual rainfall ranges from 350 to 800 mm. The main habit it occupied was the submediterranian or semi-steppe herbaceous shrub formation. Zohary and Brick (42) also pointed out that the alleged confinement of dicoccoides to a rocky or stony habitat as described by Vavilov was true only in the case of overgrazed areas. Where grazing was controlled, large and dense stands of wild emmer were observed.

Harlan and Zohary (11) reviewed the reports on the distribution of dicoccoides. Known and reasonably certain sites of wild emmer occurred in Israel, Jordan, Syria, Lebanon, Turkey, Iran, Iraq, and the U.S.S.R. (Plate I). They suggested that wild emmer could be divided into two main races. The Turkish-Iraqi race is distributed in southeast Turkey, northeast Iraq, western Iran, and the Transcaucus region of the U.S.S.R. The Palestine race is centered on the upper Jordan Valley from eastern Galilee to Mount Hermon, the Jebel Druz, and the Gilead mountains.

The variety timopheevi was first found in 1923 by Zhukovsky in Georgia, U.S.S.R. He first described it as a variety of T. dicoccoides (39) but five years later elevated it to species rank, naming it T. timopheevi (Zhuk) (40). He considered it to be a weed species seldom found in the wild state, and restricted in distribution to Georgia, U.S.S.R. Wagenaar (38) reported that T. timopheevi had a distribution covering Georgia, Nachitschevan, Armenia, Azerbaijan, U.S.S.R.; eastern Turkey; northern Iraq; and northwest Iran. In these areas it occurred sympatrically with wild emmer.

Morphology

Briggle and Reitz (5) described the characteristics of T. dicoccoides as follows:

> ... The spikes are lax, laterally compressed, and have long, stiff awns. The flattened rachis is smooth and shiny with a fringe of conspicuous hairs along the edges. The spike is extremely fragile and spikelets readily fall on the ground at maturity. Glumes are extremely tenacious, very sharply keeled, and scarbid...

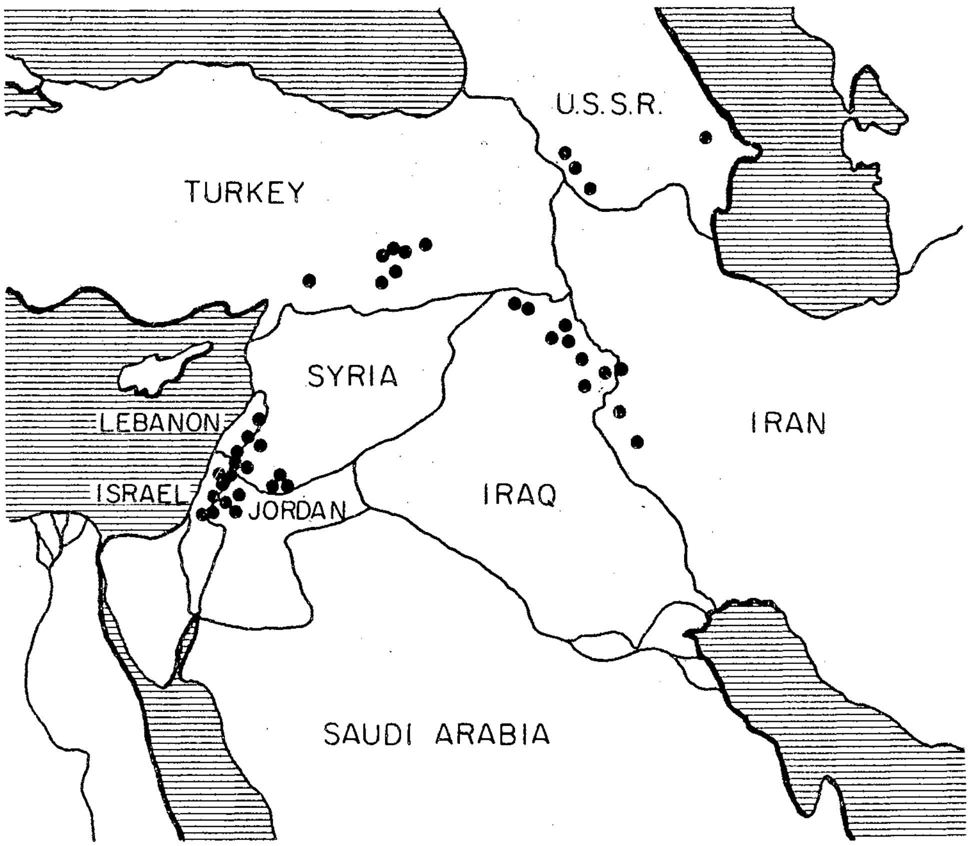
PLATE I

DISTRIBUTION OF KNOWN SITES OF WILD EMMER (AFTER HARLAN & ZOHARY, 1966)

Each dot represents a known and reasonably certain site of wild emmer (*T. turgidum* var. *dicoccoides*).

PLATE I

DISTRIBUTION OF KNOWN SITES OF WILD EMMER (AFTER HARLAN & ZOHARY, 1966)



Aaronsohn (1) noted considerable variation in morphological characters among the populations of wild emmer growing on Mount Hermon. Some had spikes that were entirely black; in others only the glumes or part of the glumes were black; in still others the awns alone were black. Sometimes the glumes were completely glabrous, sometimes very hirsute, in some populations the glumes resembled those of durum. In others, the development of the glume nerves were similar to those of *T. monococcum*.

Percival (22) in his voluminous monograph on wheat, gave a detailed description and discussed the morphological variation in wild emmer. He divided *T. dicoccoides* into five varieties on the basis of glume color and pubescence. He also noted plants exhibiting great diversity in glume shape; the size and prominence of keel, and secondary teeth; and in color and pubescence of the glume and rachis.

Zohary and Brick (42) studied the hybrid swarms between wild emmer and durum and found highly introgressed *dicoccoides* populations in several localities in the semi-steppy hilly area of the Eastern Galilee. One of the swarms included many brittle *dicoccoides*-like plants, a few plants with a tough rachis identified as the local durum variety "Etit", and a whole range of intermediates. They suggested that *dicoccoides* and cultivated durums cannot be regarded as entirely isolated from each other and most probably they are genetically interconnected.

Harlan and Zohary (11) reported that plants of the Turkish-Iraqi race of wild emmer were small, being not much larger than wild einkorn. On the other hand, plants of the Palestine race were relatively large and robust, with large seeds, heavy awns, wide leaves, and thick stems.

Briggle and Reitz (5) described the characteristics of T. timopheevi as follows:

> ... Spikes are very compact, broad across the two rowed profile, and pyramidal in shape. Awns are soft, thin, and short to midlong. The rachis is not nearly so fragile as in T. dicoccoides. A characteristic peculiar to this species is the presence of long, white, tough hairs on the leaf sheaths. Leaf blades are pubescent on both surfaces...

Cytology

The confirmation of the role of polyploidy in the evolution of wheat was a major step in wheat cytology. Sakamura in 1918 established polyploidy in wheat and showed that the three natural groups of wheat had chromosome numbers of n = 7, 14, 21 (27). Sax (28) independently also reported polyploidy in wheat. Accordingly the genome formulae AA, AABB, and AABBDD were given to the three groups (15).

Lilienfeld and Kihara (18) concluded that timopheevi had only one genome in common with the emmers. They stated that the second genome differs from that of any other wheat previously analyzed. They suggested a different origin for the second genome of timopheevi; proposing the symbols AG for the genome constitution of timopheevi.

Kostoff (16, 17) crossed timopheevi with diploid, tetraploid and hexaploid wheats. From the data he concluded that the second genome of timopheevi was partially homologous with B genome of other tetraploid wheats, and therefore designated the genome of timopheevi as AAββ.

Love (19) analyzed the chromosome pairing in hybrids of timopheevi with durum and hexaploid wheats. He concluded that timopheevi differs from other tetraploid wheats in degree only and that a certain degree of homology exists between the B genome and the second genome of timopheevi.

Sachs (26) analyzed the cytological relationships of hybrids and amphiploids of tetraploid wheats. He found considerable divergence in chromosome structure within the wild emmer, and suggested that timopheevi may have diverged in the same way from an original 4x chromosome prototype. He proposed that all tetraploid wheat species could be derived from the original 28 chromosome prototype. He thought that the sterility of hybrids of tetraploid species with timopheevi was due to recombination between chromosomes containing non-homologous segments. He suggested that timopheevi be given the same genome formula as other tetraploid wheats.

Bowden (3) proposed a new classification for the genus Triticum based on morphological as well as cytogenetic differences. He included all the tetraploid wheats under the species T. turgidum. He considered that the varieties dicoccoides, timopheevi, zhukovsky, and tumanianii belong to the original wild population and that the remainder of all allotetraploid wheats had been brought under cultivation from some of these populations.

Zohary and Feldman (43) suggested that tetraploid wheats had a modified genome side by side with an unaltered one. To them the modified genomes of existing polyploid forms represent new chromosomal recombinations, each derived from two or more original diploid genomes. On these grounds, they expected wide intervarietal chromosomal differences in wild emmer.

Wagenaar (37, 38) suggested that two genes are involved in the degree of meiotic chromosome pairing of hybrids between timopheevi and other tetraploid wheats. The genetic asynaptic system was in homozygous condition in timopheevi and asynapsis was only expressed in heterozygous condition in interspecific hybrids. He proposed that timopheevi originated from dicoccoides through this genetic isolation mechanism. He supported the ideas of giving timopheevi the genome formula AABB.

Feldman (7) studied the relative chromosomal differentiation in the two genomes of timopheevi using telocentric chromosomes as cytological markers. He studied the pairing behaviour of 19 of the 28 chromosome arms of timopheevi in F_1 hybrids with T. aestivum (Chinese Spring) having known telocentric chromosomes and the amphiploid timopheevi-T. aegilops. The results indicated that most of the pairing failure in hybrids involved the B genome of T. aestivum and the corresponding genome of timopheevi. He interpreted this to mean that structural differences rather than genes (as suggested by Wagenaar /38/) were responsible for lack of pairing in timopheevi hybrids. He further suggested that the second genome of timopheevi be designated as B^t, and both B^t genome of timopheevi and B genome of other tetraploid wheats represent new genomic combinations. Feldman (8) reported that timopheevi contains a gene system on chromosome 5 B identical with that found in 5 B of T. aestivum. In hybrids, this timopheevi gene system completely compensated the nullisomic condition of "Chinese Spring" 5 B.

Harlan and Zohary (11) reviewed the cytogenetic evidence of wild emmer as well as the distribution and morphology of the group. As previously stated in this chapter, they tentatively proposed two main races of wild emmer, the Palestine race and the Turkish-Iraqi race. These two races were considered to be cytogenetically as well as morphologically distinct. Other workers had found that hybrids between the Palestine race and most of tetraploid cultivated wheats, including cultivated emmer, were fertile and chromosomes paired regularly.

There was every evidence of close relationship between the Palestine race and other tetraploid types except _timopheevi_. The Turkish-Iraqi race, on the other hand, showed poor pairing and sterility when crossed with the same cultivated tetraploid wheats. It had, however, been shown that there was close affinity between the Turkish-Iraqi race and _timopheevi_. Harlan and Zohary (11), indicating the need for further evidence to arrive at definite conclusions, suggested that most of modern tetraploid cultivated wheats stemmed from the Palestine race now found in the upper Jordan watershed. They also suggested that Turkish-Iraqi race did no more than contribute to the _timopheevi_ complex.

Biochemical differences between _timopheevi_ and other tetraploid wheats have been reported. Rees and Walters (24) found lower content of DNA in _timopheevi_ than in durum. Johnson (14) showed that _timopheevi_ had six fast-moving albumin homologues of protein spectra while _dicoccoides_ and other tetraploid wheats showed eight.

CHAPTER III

MATERIALS AND METHODS

Accessions

The materials involved in this study consisted of several types of tetraploid wheats. These included Israeli and Turkish accessions of wild emmer, a collection of timopheevi, cultivated emmers from several countries, as well as one collection each of turgidum and carthlicum (Table I).

Ten accessions of wild emmer (T. turgidum L. emend. var. dicoccoides /Körn/ Bowden), consisting of four from Israel and six from Turkey were used in the morphological and cytological studies. These accessions were provided by Dr. J. R. Harlan, formerly Professor of Agronomy, Oklahoma State University, Stillwater; now Professor of Genetics, University of Illinois, Urbana. The general sites from which these collections were made are shown in Plate II. More detailed collection information from field notes is listed below:

A. 11140: Beit Meir, 12 km west of Jerusalem, Israel.

A. 11147: north of Sea of Galilee, Israel.

A. 11150: north of Sea of Galilee, Israel.

A. 11153: north of Sea of Galilee, Israel.

A. 11182: 26 km north of Siverek-Çermik Road, Turkey.

A. 11186: west of town of Karaca Dağ, Turkey.

A. 11187: near Hilar, Turkey.

TABLE I

ACCESSIONS INVESTIGATED

Variety or Cultivar	Accession (A.) or Plant Introduction (P.I.) Number	Country of Origin
T. turgidum var. *dicoccoides* (wild emmer)	A. 11140	Israel
T. turgidum var. *dicoccoides* (wild emmer)	A. 11147	Israel
T. turgidum var. *dicoccoides* (wild emmer)	A. 11150	Israel
T. turgidum var. *dicoccoides* (wild emmer)	A. 11153	Israel
T. turgidum var. *dicoccoides* (wild emmer)	A. 11182	Turkey
T. turgidum var. *dicoccoides* (wild emmer)	A. 11186	Turkey
T. turgidum var. *dicoccoides* (wild emmer)	A. 11187	Turkey
T. turgidum var. *dicoccoides* (wild emmer)	A. 11189	Turkey
T. turgidum var. *dicoccoides* (wild emmer)	A. 11191	Turkey
T. turgidum var. *dicoccoides* (wild emmer)	A. 11194	Turkey
T. turgidum var. *timopheevi*	P.I. 94760	U.S.S.R.
T. turgidum cultivar dicoccon (emmer)	P.I. 58788-2	Ethiopia
T. turgidum cultivar dicoccon (emmer)	A. 11218	Ethiopia
T. turgidum cultivar dicoccon (emmer)	A. 11221	Ethiopia
T. turgidum cultivar dicoccon (emmer)	P.I. 12213	India
T. turgidum cultivar dicoccon (emmer)	P.I. 94624	Iran
T. turgidum cultivar dicoccon (emmer)	P.I. 56235	U.S.S.R.
T. turgidum cultivar dicoccon (emmer)	P.I. 221398	Yugoslavia
T. turgidum cultivar dicoccon (emmer)	P.I. 221403	Yugoslavia
T. turgidum cultivar dicoccon (emmer)	A. 11119	Yugoslavia
T. turgidum cultivar turgidum	--	Not known
T. turgidum cultivar carthlicum	P.I. 78812	Iran

PLATE II

LOCATION OF *T. TURGIDUM* VAR. *DICOCCOIDES* ACCESSIONS

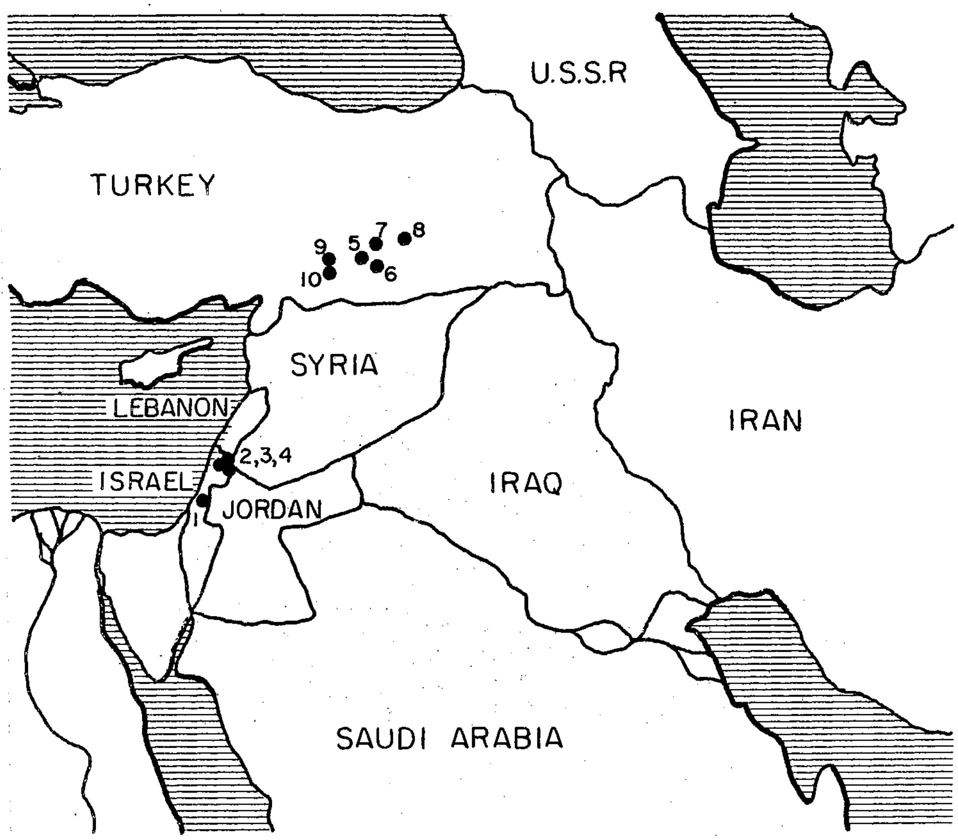
Each dot represents the location of an accession of wild emmer.

1. A. 11140 from Israel.
2. A. 11147 from Israel.
3. A. 11150 from Israel.
4. A. 11153 from Israel.

5. A. 11182 from Turkey.
6. A. 11186 from Turkey.
7. A. 11187 from Turkey.
8. A. 11189 from Turkey.
9. A. 11191 from Turkey.
10. A. 11194 from Turkey.

PLATE II

LOCATION OF T. TURGIDUM VAR. DICOCCOIDES ACCESSIONS



A. 11189: west of Juniper, 9 km south of Lice, Turkey.

A. 11191: 5 km south of Maras-Malatya fork toward Gaziantep, Turkey.

A. 11194: 12 to 16 km south of Malatya-Maras turn off, Turkey.

The accession of T. turgidum L. em. var. timopheevi (Zhuk) Bowden resulted from a selection made at Madison, Wisconsin, from an introduction (P.I. 94760) previously collected at Tiftis, Georgia, the U.S.S.R. This accession had been grown previously at Stillwater, Oklahoma, and was obtained from the Small Grains Section, Agronomy Department, Oklahoma State University.

Three of the nine accessions of the emmer (T. turgidum L. em. cultivar dicoccon /Schrank/ Bowden) used in the study (A. 11119, A. 11218, and A. 11221) were also provided by Dr. Harlan. The other six emmer accessions came from a nursery consisting of part of the world wheat collection which had been grown at Stillwater in 1959.

The accession of T. turgidum L. em. cultivar carthlicum (Nevski) Bowden, originally from Iran, also came from the world wheat collection. The collection of T. turgidum L. em. cultivar turgidum (L) Bowden, was available at the Oklahoma Agricultural Experiment Station, Stillwater. The country of origin of this accession is unknown.

Experimental Procedures

For the morphological studies experiments were laid out in a randomized complete block design with 22 entries (accessions) in each block. There were three blocks. The experimental unit was a plot containing one plant. This experiment was conducted in the Small Grains plastic greenhouse at Oklahoma State University Agronomy Farm in 1967. Due to the heterogeneity of the environment in the plastic greenhouse, the randomized complete block design was inappropriate. Therefore no statistical analysis was attempted.

Mature plants were pressed for herbarium specimens. For each accession two spikelets from each of the three plants were analyzed. In order to make certain that the spikelets of different forms would be comparable, only the spikelets from the middle portion of the mature spike were used. For each accession, 21 characters were studied with the aid of a dissection microscope. The qualitative and quantitative characters along with the units of description are given in Table II. For measuring these characters, the description of Sarkar and Stebbins (29) and Briggle and Reitz (5) were used.

Out of 20 morphological spike characteristics, 11 were qualitative and 9 were quantitative in nature. For the qualitative characters, the frequency was scored. For quantitative characters, averages and ranges were calculated, but no statistical analysis was attempted. For the 21st character, leaf pubescence, presence or absence in 3 plants for each accession was observed.

The qualitative and quantitative morphological characters were observed to find out the possible relationships among the tetraploid wheat groups. An attempt was made to show the morphological differences between Israeli and Turkish <u>dicoccoides</u> and their relationship to <u>timopheevi</u> by using Anderson's pictorialized scatter diagrams (2).

In order to determine growth habit and relative winterhardiness, the accessions were planted in the field during the fall of 1966, and again in the spring of 1967. The plots consisted of single 5-foot

TABLE II

MORPHOLOGICAL CHARACTERS STUDIED

Character	Unit of Description[1]
Leaf Pubescence	: - Absent, + Present
Spikelets per spike	: Number
Spikelet	
Rachis internode	
Length	: In cms
Width	: In cms
Pubescence on rachis internode edge	: - Absent, + Sparse, ++ Dense
Pubescence at base of spikelet	: - Absent, + Sparse, ++ Dense
Fertile florets for spikelet	: Number
Glume	
Length	: In cms
Width	: In cms
Pubescence	: - Absent, + Sparse, ++ Dense
Texture of margins	: Thin, Thick
Number of veins	
Narrow side	: Number
Broad side	: Number
Shoulder shape[2]	: Wanting, Oblique, Round, Square, Elevated, Apiculate
Beak shape[2]	: Obtuse, Acute, Acuminate
1st Lemma	
Awn length	: In cms
Lemma length	: In cms
Pubescence	: - Absent, + Sparse, ++ Dense
Veins	: Number
2nd Lemma	
Awn length	: In cms
Lemma length	: In cms

[1]The description of Sarkar and Stebbins (29) was followed except where mentioned.

[2]The description of Briggle and Reitz (5) was followed.

rows for each accession. The seeding rate varied from 20 to 30 seeds per plot depending on the amount of available seed.

Percival (22, 23) reported the presence of 2 to 6 vascular bundles in the coleoptile of wild emmer and Ethiopian and Indian cultivated emmers. All other wheat groups had been reported to have only two. In order to determine the distribution pattern of this character among all accessions used in the study, the number of vascular bundles in the coleoptile were counted. For these investigations, the seed was germinated in petri dishes and when the plumule was 3 cms in length, it was preserved in an FAA solution (40% formaldehyde, glacial acetic acid, and absolute alcohol in a 1:1:18 proportion). Transverse sections of the plumule were taken with a razor and stained with safranin. Under a dissection microscope the number of vascular bundles was counted for three sections at different points along the coleoptile and six coleoptiles for each accession were examined.

To study the cytogenetic relationships of dicoccoides with other tetraploid wheats, various combinations of crosses were attempted as shown in Table III. Crossing work was done in the greenhouse in the spring of 1965 and also in the spring of 1966. The approach method (6) was used in the crossing work. Reciprocal crosses were made in some cases but were not maintained separate. A total of 5,046 florets were emasculated and 1,124 seeds were obtained, resulting in 22.2% seed set. The crosses along with their parents were grown in the greenhouse during the spring of 1966 and the spring of 1967 and in growth chambers during the summer of 1966. For each F_1 hybrid, at least 1 tiller per cross was grown to maturity.

For the cytological studies, the parent and F_1 hybrid spikes at

TABLE III

CROSSES ATTEMPTED

dicoccoides (Israel)[1]	X	*timopheevi* (P.I. 94760)
	X	dicoccon (all accessions)[2]
	X	turgidum
	X	carthlicum (P.I. 78812)
	X	*dicoccoides* (Turkey)[3]
dicoccoides (Turkey)[3]	X	*timopheevi* (P.I. 94760)
	X	dicoccon (all accessions)[2]
	X	turgidum
	X	carthlicum (P.I. 78812)
timopheevi (P.I. 94760)	X	dicoccon (all accessions)[2]
	X	turgidum
	X	carthlicum (P.I. 78812)

[1]*dicoccoides* (Israel) includes A. 11140, A. 11147, A. 11150 and A. 11153.

[2]dicoccon (all accessions) includes A. 11119, A. 11218, A. 11221, P.I. 12213, P.I. 56235, P.I. 58788-2, P.I. 94764, P.I. 221398, and P.I. 221403.

[3]*dicoccoides* (Turkey) includes A. 11182, A. 11186, A. 11187, A. 11189, A. 11191, and A. 11194.

the proper stage of development were fixed in a modified Cornoy's fluid (absolute alcohol, glacial acetic acid and chloroform in a 6:3:1 proportion). Fixation was done for the most part between 9:30 a.m. and 11:00 a.m. The fixed material was stored in the refrigerator until smear preparations of the microsporocyte cells in acetocaramine were made according to Belling's method (4). For each cross chromosome pairing during meiotic metaphase I, was evaluated by scoring twenty-five pollen mother cells. The smears were analyzed by using an oil immersion objective at a magnification of X1425. Photomicrographs of various smears were taken at approximately X1350 magnification. The parents and F_1 hybrids were selfed by bagging and fertility was determined by comparing seed set to total number of lateral mature florets. Fertility was expressed in percent seed set.

CHAPTER IV

EXPERIMENTAL RESULTS

Morphology

The primary interest in the morphological phase of this investigation was to determine the phenotypic relationship between the Israeli and Turkish wild emmers and their phenotypic relationship to timopheevi. Representative figures of spikes, spikelets, glumes, lemmas, paleas, and seed of dicoccoides from Israel and Turkey, timopheevi, and dicoccon are shown in Plate III. Relative to the Turkish accessions, the Israeli dicoccoides had large lax heads, heavy awns, large spikelets, dense pubescence on the rachis internode edge and spikelet base, and large seeds. The Turkish dicoccoides were characterized by small, compact heads, fine-textured awns, small spikelets, sparse pubescence on the rachis internode edge and spikelet base, and small seeds. The Israeli wild emmers were robust with thick stems, and wide leaves which were pale green in color. They were early in maturity, less winterhardy than the Turkish accessions, and showed some spring growth habit. The Turkish wild emmers were small in size with thin stems, and narrow leaves which were dark green in color. They were late in maturity, more winterhardy than the Israeli accessions and showed winter type growth habit.

The four characters which showed differences between Israeli and Turkish wild emmers in scatter diagrams are given in Table IV.

PLATE III

SPIKE MORPHOLOGY IN DICOCCOIDES, TIMOPHEEVI, AND DICOCCON

In each picture the spike, spikelet, glume, lemma, palea, and seed are shown. All pictures are of the same magnification.

Legend:

Figure 1: dicoccoides accession A. 11150 from Israel.

Figure 2: dicoccoides accession A. 11187 from Turkey.

Figure 3: dicoccon accession A. 11221 from Ethiopia.

Figure 4: timopheevi accession P.I. 94760 from the U.S.S.R.

PLATE III

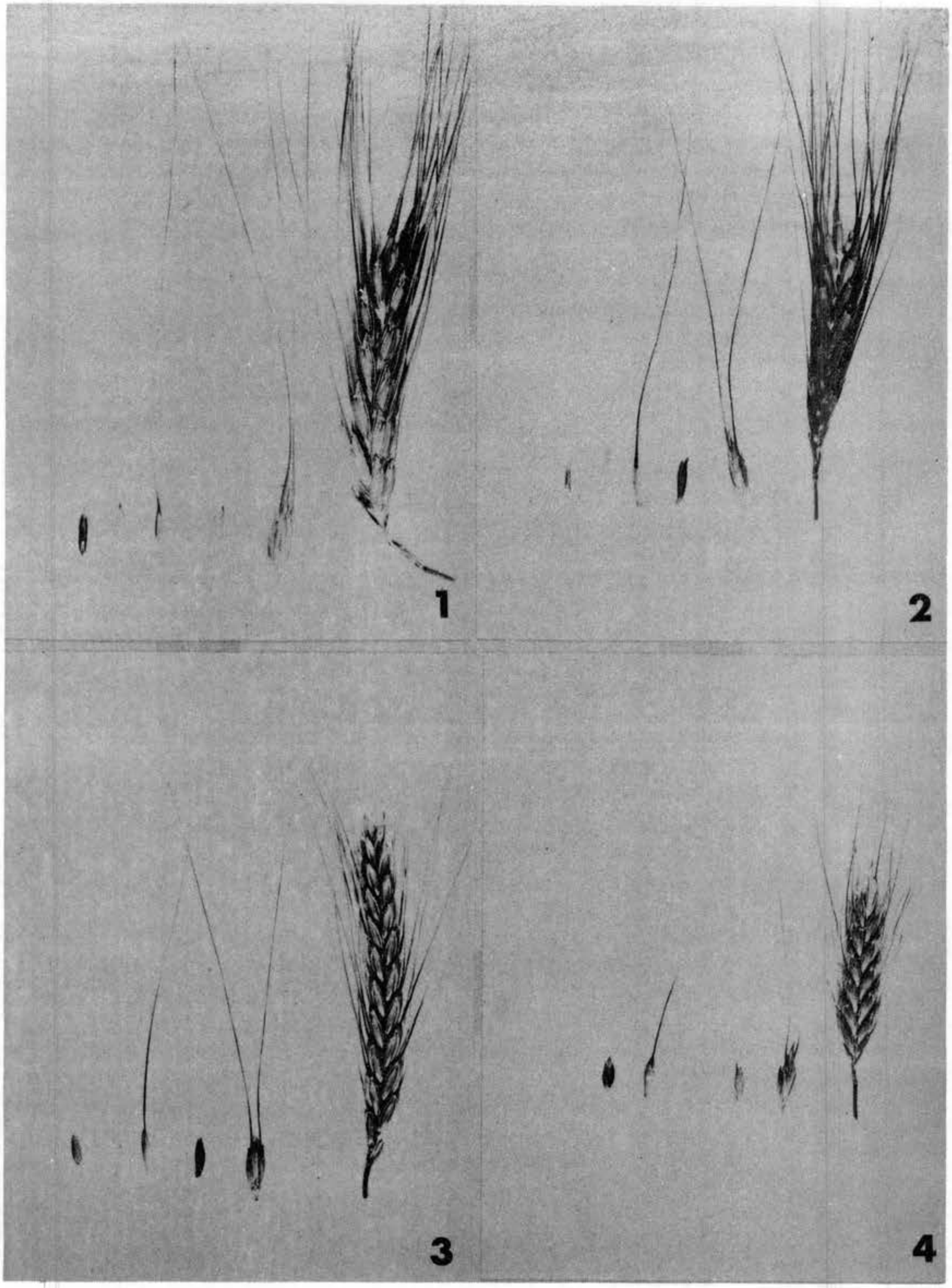


TABLE IV

MORPHOLOGICAL DATA OF FOUR CHARACTERS OF DICOCCOIDES AND TIMOPHEEVI ACCESSIONS[1]

Accession	Number	Country	Spikelets per Spike (Number)	Rachis Internode Length (cm)	Rachis Internode Width (cm)	1st Lemma Length (cm)
dicoccoides	A. 11140	Israel	13.5	0.52	0.24	1.18
			13-15	0.48-0.58	0.22-0.24	1.10-1.23
dicoccoides	A. 11147	Israel	14.3	0.54	0.33	1.43
			13-15	0.50-0.60	0.30-0.37	1.40-1.50
dicoccoides	A. 11150	Israel	13.0	0.58	0.31	1.41
			12-15	0.54-0.62	0.28-0.33	1.32-1.51
dicoccoides	A. 11153	Israel	13.0	0.49	0.31	1.19
			11-14	0.44-0.53	0.28-0.35	1.13-1.22
Average for Israeli dicoccoides			13.5	0.53	0.30	1.30
			11-15	0.44-0.62	0.22-0.37	1.10-1.51
dicoccoides	A. 11182	Turkey	21.3	0.37	0.22	1.40
			21-22	0.34-0.40	0.20-0.23	1.30-1.45
dicoccoides	A. 11186	Turkey	15.5	0.39	0.22	1.30
			15-17	0.30-0.50	0.20-0.24	1.24-1.35
dicoccoides	A. 11187	Turkey	16.1	0.47	0.23	1.51
			15-20	0.42-0.52	0.22-0.27	1.42-1.60
dicoccoides	A. 11189	Turkey	17.8	0.49	0.22	1.27
			15-20	0.45-0.55	0.20-0.23	1.23-1.30
dicoccoides	A. 11191	Turkey	15.0	0.45	0.22	1.42
			10-20	0.42-0.47	0.20-0.23	1.30-1.52
dicoccoides	A. 11194	Turkey	12.8	0.41	0.23	1.26
			11-14	0.37-0.46	0.20-0.26	1.15-1.30
Average for Turkish dicoccoides			16.4	0.43	0.22	1.36
			10-22	0.30-0.55	0.20-0.27	1.15-1.60
timopheevi	P.I. 94760	U.S.S.R.	24.0	0.31	0.19	1.21
			21-26	0.30-0.37	0.16-0.23	1.16-1.30

[1]For each accession 6 spikelets were studied. Average and range were given.

The Israeli wild emmers had fewer spikelets per spike, and longer and wider rachis internodes than the Turkish wild emmers. Pictorialized scatter diagrams (Plates IV and V) of these characters showed that the wild emmer accessions from Israel and Turkey fall into two distinct groups without any overlapping. Pictorialized scatter diagrams (Plate VI) showed that timopheevi falls close to the Turkish dicoccoides in these characters. All Israeli wild emmer accessions had glabrous leaves. The Turkish dicoccoides accessions 11189 and 11191 had pubescent leaves while the other four Turkish accessions had glabrous leaves. The variety timopheevi showed typical leaf pubescence.

The morphological data of 12 qualitative and 5 quantitative characters for the Israeli and Turkish dicoccoides and timopheevi accessions is given in Appendix Tables XII and XIII. For dicoccon, turgidum and carthlicum accessions, morphological data on 12 qualitative and 9 quantitative characters is given in Appendix Tables XIV and XV. For qualitative characters the frequency and for quantitative characters averages and ranges were given. No statistical analysis was presented. The characters were quite variable among accessions and did not show any specific pattern. They were of little value in separating the Israeli and Turkish dicoccoides and timopheevi and other tetraploid wheats and are consequently not discussed in any detail.

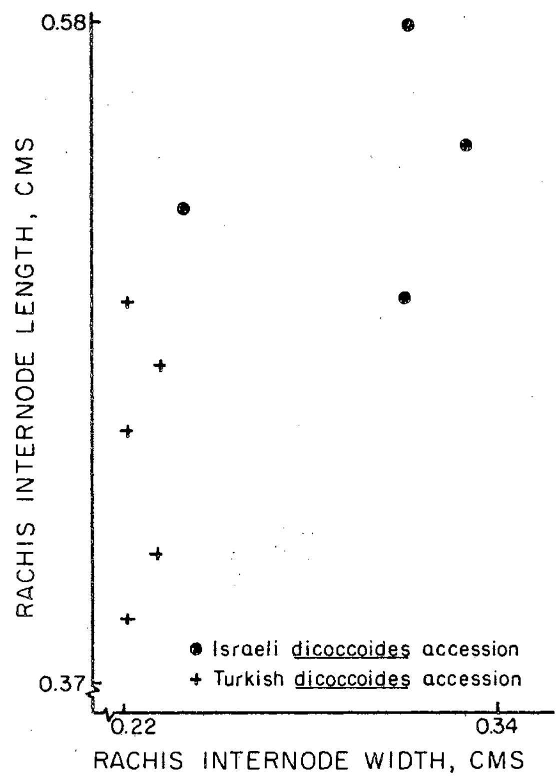
The number of vascular bundles in the coleoptile of all accessions is shown in Table V. Except for the emmer accessions from Ethiopia and India, all accessions had two vascular bundles of the same size. Accession 11221 of emmer from Ethiopia had 3 vascular bundles, two of the same size and smaller. Accession 11218 of emmer from Ethiopia had 5 vascular bundles, 2 larger ones of the same size and 3 smaller ones

PLATE IV

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL DATA OF THE ISRAELI AND THE TURKISH DICOCCOIDES ACCESSIONS

PLATE IV

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL DATA OF THE ISRAELI AND THE TURKISH DICOCCOIDES ACCESSIONS



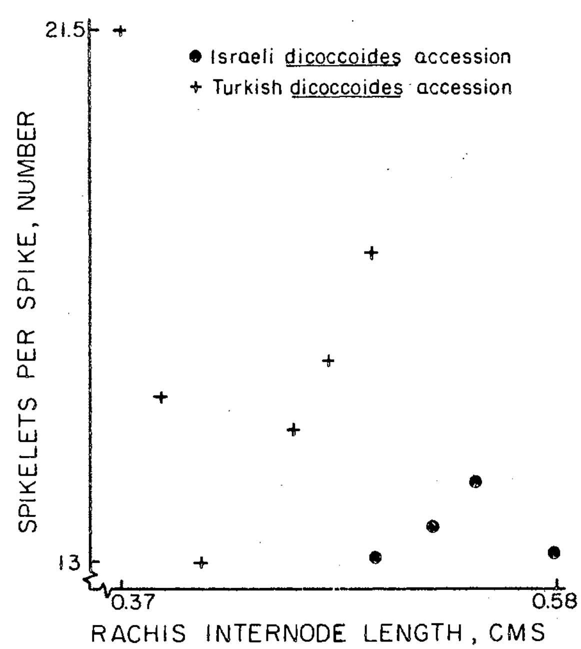
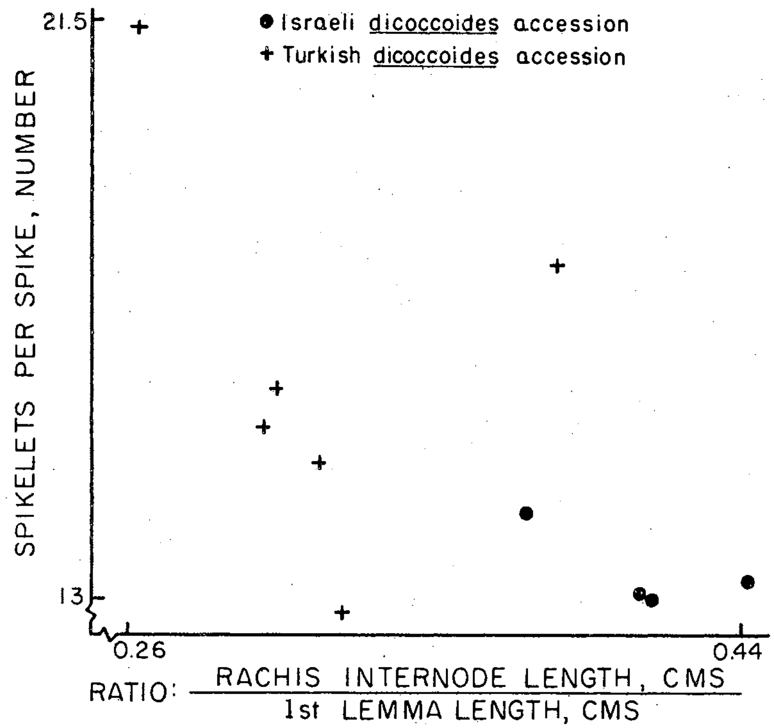


PLATE V

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL DATA OF THE ISRAELI AND THE TURKISH DICOCCOIDES ACCESSIONS

PLATE V

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL DATA OF THE ISRAELI AND THE TURKISH DICOCCOIDES ACCESSIONS



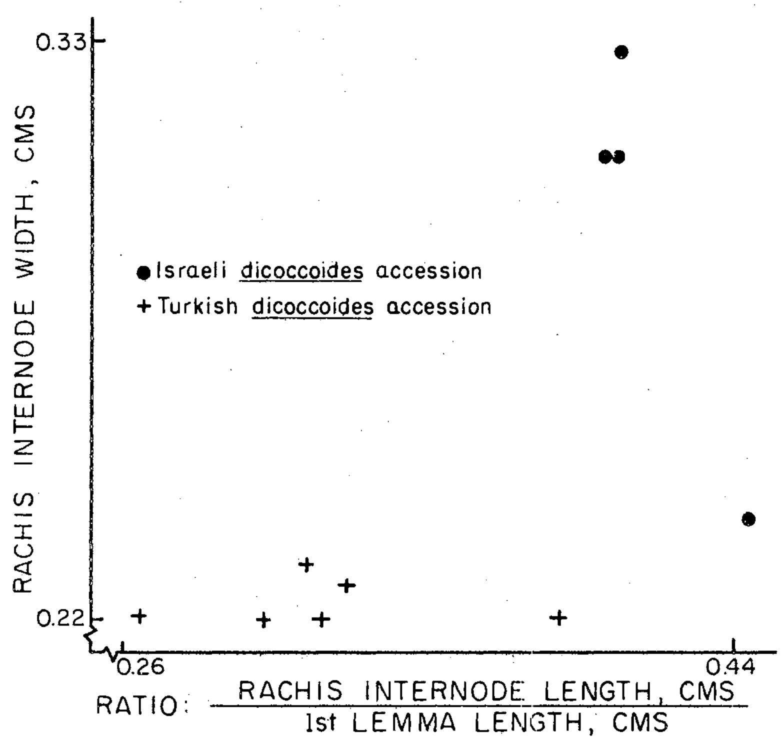


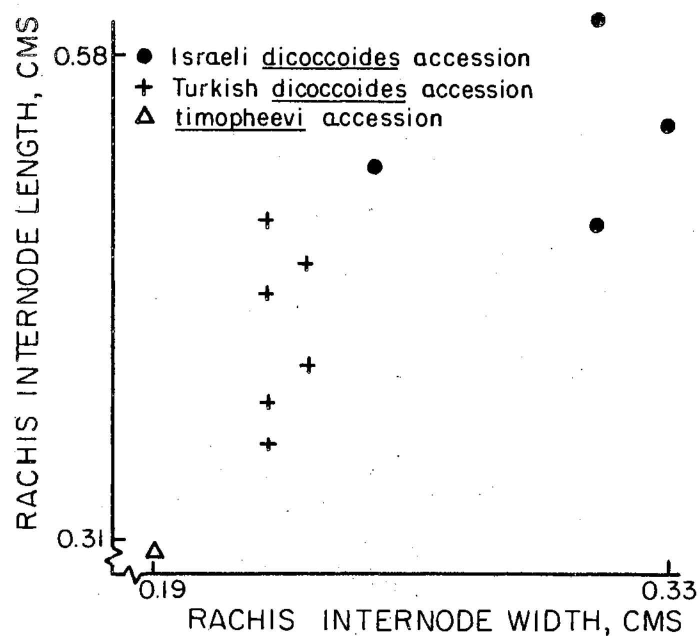
PLATE VI

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL DATA OF DICOCCOIDES AND TIMOPHEEVI ACCESSIONS

PLATE VI

PICTORIALIZED SCATTER DIAGRAMS FROM THE MORPHOLOGICAL

DATA OF DICOCCOIDES AND TIMOPHEEVI ACCESSIONS



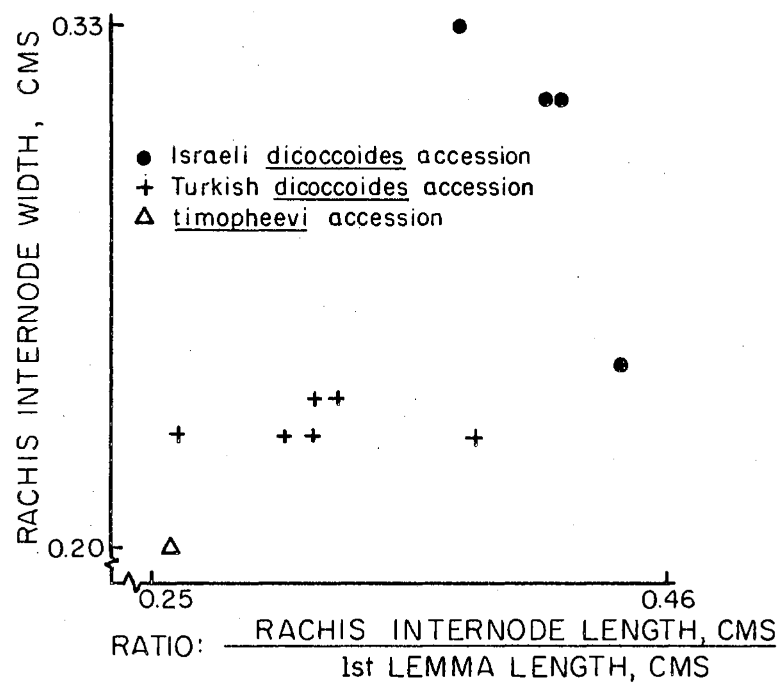


TABLE V

NUMBER OF VASCULAR BUNDLES IN THE COLEOPTILE

Accession	Number	Country	Number of Vascular Bundles[1]	Remarks
dicoccoides	A. 11140	Israel	2	Both same size
dicoccoides	A. 11147	Israel	2	Both same size
dicoccoides	A. 11150	Israel	2	Both same size
dicoccoides	A. 11153	Israel	2	Both same size
dicoccoides	A. 11182	Turkey	2	Both same size
dicoccoides	A. 11186	Turkey	2	Both same size
dicoccoides	A. 11187	Turkey	2	Both same size
dicoccoides	A. 11189	Turkey	2	Both same size
dicoccoides	A. 11191	Turkey	2	Both same size
dicoccoides	A. 11194	Turkey	2	Both same size
dicoccon	A. 11119	Yugoslavia	2	Both same size
dicoccon	P.I. 221403	Yugoslavia	2	Both same size
dicoccon	P.I. 12213	India	5	2 large, 2 medium, and 1 small in size
dicoccon	A. 11218	Ethiopia	5	2 large, 3 small in size
dicoccon	A. 11221	Ethiopia	3	2 large, 1 small in size
timopheevi	P.I. 94760	U.S.S.R.	2	Both same size
turgidum	--	--	2	Both same size
carthlicum	P.I. 78812	Iran	2	Both same size

[1]Average of 3 sections of each coleoptile and 6 coleoptiles of each accession.

which were equal in size. Accession P.I. 12213 of emmer from India had 5 vascular bundles, 2 large and equal in size, 2 medium and equal in size, and 1 small one.

Cytology

The data on cytology and seed set of some accessions is given in Table VI. All accessions had good chromosome pairing (generally 14 closed bivalents) during meiotic metaphase I and exhibited high fertility. Occasionally a few cells with twelve bivalents and one quadrivalent were noticed. Fertility ranged from 58% to 97% seed set.

The chromosome association at meiotic metaphase I and fertility of F_1 hybrids of Israeli dicoccoides with other tetraploid wheats is given in Table VII. The mean number of univalents, bivalents, trivalents, quadrivalents, and multivalents and their range for each hybrid is given. Three Israeli wild emmer accessions were involved as hybrids with timopheevi and all showed similar chromosome pairing with an average of 7.1 univalents, 7.6 bivalents, 0.5 trivalents, and 1.0 quadrivalent. Cells with 4 to 14 univalents, 4 to 10 bivalents, 0 to 2 trivalents, and 0 to 3 quadrivalents were observed (Plate VII, Figure 1, 2, and 3). In most of the cells more than half of the bivalents and most of the trivalents and quadrivalents were with open configuration. The F_1 hybrids were sterile when selfed by bagging (Table VII). The three F_1 hybrids of two Israeli dicoccoides accessions with two dicoccon accessions showed perfect chromosome pairing with 14 bivalents (Plate VII, Figure 4) and good fertility (29% seed set). The hybrid of Israeli dicoccoides with carthlicum showed good chromosome pairing (13.7 bivalents), but fertility was very low (2% seed set). The hybrids

TABLE VI

CYTOLOGY AND SEED SET DATA OF ACCESSIONS

Accession	Number	Country	Chromosome association at meiotic metaphase I[1]					Fertility
			I	II	III	IV	V + VI	(% Seed Set)
dicoccoides	A. 11150	Israel	0	13.90 12-14	0	0.05 0-1	0	97
dicoccoides	A. 11187	Turkey	0	13.87 12-14	0	0.07 0-1	0	93
dicoccoides	A. 11191	Turkey	0	14.00 14	0	0	0	84
timopheevi	P.I. 94760	U.S.S.R.	0	13.87 12-14	0	0.07 0-1	0	93
dicoccon	A. 11221	Ethiopia	0	14.00 14	0	0	0	75
turgidum	--	--	0	14.00 14	0	0	0	good
carthlicum	P.I. 78812	Iran	0	13.07 12-14	0	0.07 0-1	0	58

[1]Average number and range of configurations for 25 cells in each accession. I = univalents; II = bivalents; III = trivalents; IV = quadrivalents; V + VI = pentavalents and hexavalents.

TABLE VII

CYTOLOGY AND SEED SET DATA OF F_1 HYBRIDS OF ISRAELI DICOCCOIDES ACCESSIONS WITH OTHER TETRAPLOID WHEATS

Cross	Chromosome association at meiotic metaphase I[1]					Fertility
	I	II	III	IV	V + VI	(% seed set)
dicoccoides (A.11140, Israel) X timopheevi (P.I.94760, U.S.S.R.)	6.12 4-10	9.07 8-10	0.25 0-1	0.75 0-2	0	0
dicoccoides (A.11147, Israel) X timopheevi (P.I.94760, U.S.S.R.)	9.28 4-14	7.33 5-10	0.28 0-1	0.81 0-2	0	0
dicoccoides (A.11150, Israel) X timopheevi (P.I.94760, U.S.S.R.)	5.93 2-8	6.47 4-9	1.00 0-2	1.53 2-3	0	0
Average and range for dicoccoides (Israel) X timopheevi	7.11 4-14	7.62 4-10	0.51 0-2	1.03 0-3	0	0
dicoccoides (A.11147, Israel) X dicoccon (A.11221, Ethiopia)	0	14.00 14	0	0	0	-
dicoccoides (A.11153, Israel) X dicoccon (A.11119, Yugoslavia)	0	14.00 14	0	0	0	22
dicoccoides (A.11153, Israel) X dicoccon (A.11221, Ethiopia)	0	14.00 14	0	0	0	36
Average and range for dicoccoides (Israel) X dicoccon	0	14.00 14	0	0	0	29
dicoccoides (A.11140, Israel) X turgidum	0	14.00 14	0	0	0	80
dicoccoides (A.11150, Israel) X carthlicum (P.I.78812, Iran)	0	13.73 12-14	0	0.13 0-1	0	2
dicoccoides (A.11147, Israel) X dicoccoides (A.11186, Turkey)	0	14.00 14	0	0	0	85
dicoccoides (A.11150, Israel) X dicoccoides (A.11186, Turkey)	0	12.67 12-14	0	0.67 0-1	0	30
dicoccoides (A.11150, Israel) X dicoccoides (A.11189, Turkey)	8.73 5-14	7.67 5-11	0.13 0-1	0.80 0-3	0.07 0-1	0

[1]Average number and range of various configurations for 25 cells in each hybrid are listed. I = univalent; II = bivalent; III = trivalent; IV = quadrivalent; V + VI = pentavalents and hexavalents.

PLATE VII

CYTOLOGY OF TETRAPLOID WHEAT F_1 HYBRIDS

All figures ca. X1350.

Legend:

Figure 1. Metaphase I in dicoccoides (A. 11147, Israel) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 7 univalents, 9 bivalents, and 1 trivalent.

Figure 2. Metaphase I in dicoccoides (A. 11150, Israel) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 2 univalents, 10 bivalents, and 2 trivalents.

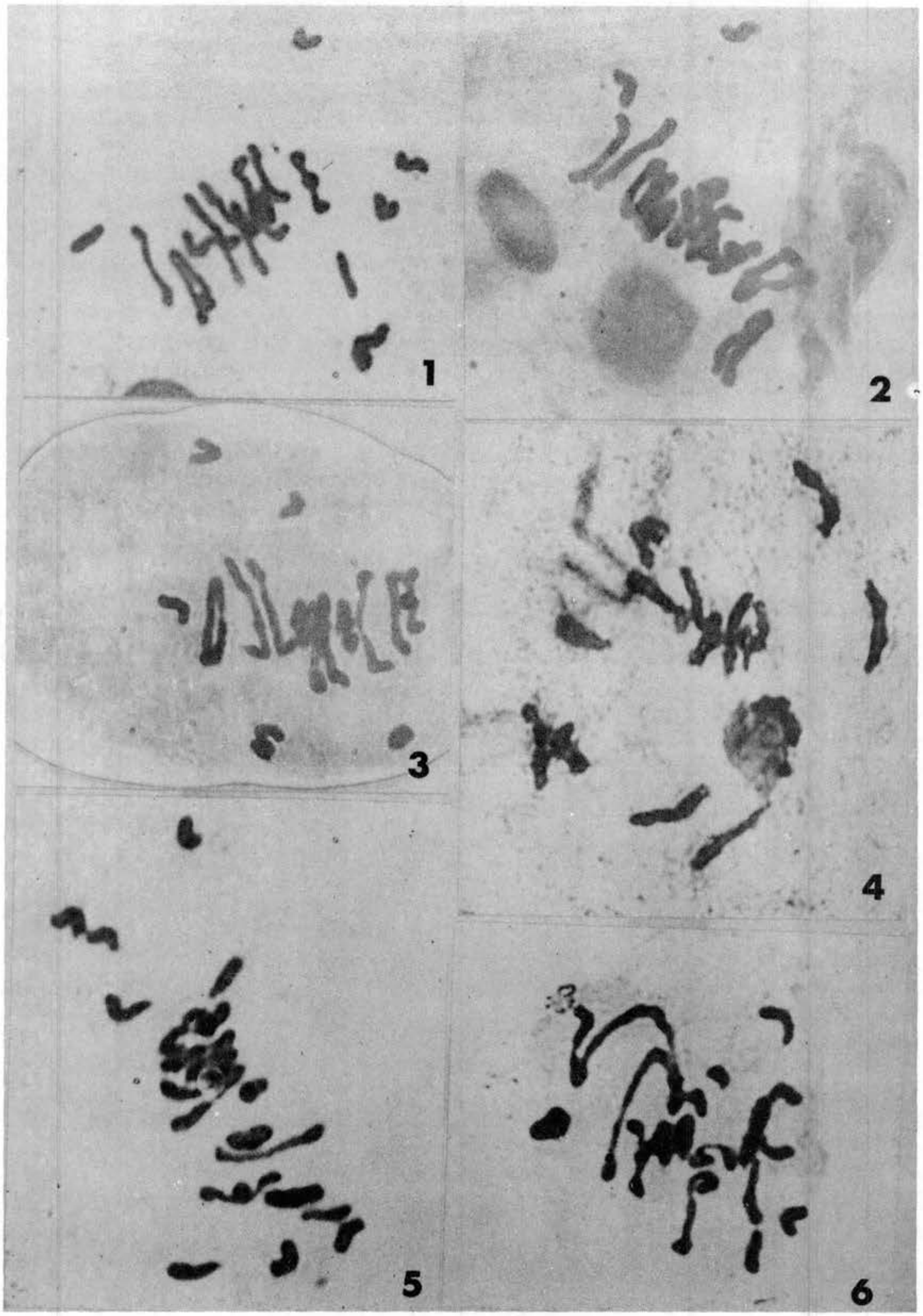
Figure 3. Metaphase I in dicoccoides (A. 11150, Israel) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 7 univalents, 9 bivalents, and 1 trivalent.

Figure 4. Diakinesis in dicoccoides (A. 11153, Israel) X dicoccon (A. 11119, Yugoslavia) hybrid showing 14 bivalents.

Figure 5. Metaphase I in dicoccoides (A. 11187, Turkey) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 7 univalents, 9 bivalents, and 1 trivalent.

Figure 6. Metaphase I in dicoccoides (A. 11187, Turkey) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 3 univalents, 9 bivalents, 1 trivalent, and 1 quadrivalent.

PLATE VII



of Israeli dicoccoides (A. 11147, A. 11150) with dicoccoides accession 11186 from Turkey had good chromosome pairing (an average of 13.4 bivalents and many cells with 14 bivalents) and 58% seed set (Plate VIII, Figure 4). However, the hybrid of dicoccoides A. 11150 from Israel with dicoccoides A. 11189 from Turkey had poor chromosome pairing with an average of 7.7 bivalents, most of which were of open configuration. The hybrid was self sterile. Cells with 5 to 14 univalents, 5 to 11 bivalents, 0 to 1 trivalents, 0 to 3 quadrivalents, and one cell with a chain of 5 chromosomes were observed for this hybrid (Plate VIII, Figure 5).

The chromosome association and fertility of F_1 hybrids of Turkish wild emmers with other tetraploid wheats is given in Table VIII. Three accessions of dicoccoides from Turkey (A. 11182, A. 11186, A. 11187) showed similar chromosome behaviour in timopheevi hybrids. They showed an average of 7.9 univalents, 8.1 bivalents (mostly open), 0.2 trivalents, and 0.8 open quadrivalents. In these hybrids cells with 2 to 16 univalents, 5 to 12 bivalents, 0 to 1 trivalents, 1 to 2 quadrivalents and one cell with a chain of six chromosomes were observed (Plate VII, Figures 5 and 6; Plate VIII, Figure 1). These hybrids were completely sterile.

Two dicoccoides accessions (A. 11182, A. 11194) from Turkey were involved in crosses with dicoccon and these hybrids showed good chromosome pairing and high fertility. There was an average of 13.8 bivalents (mostly closed) with a range of 12 to 14 bivalents and regular anaphase (Plate VIII, Figures 2 and 3) and 83% seed set. Only one Turkish dicoccoides accession (A. 11182) was involved in crosses with turgidum and carthlicum. These hybrids showed good chromosome pairing and high

PLATE VIII

CYTOLOGY OF TETRAPLOID WHEAT F_1 HYBRIDS

All figures ca. X1350.

Legend:

Figure 1. Metaphase I in the dicoccoides (A. 11187, Turkey) X timopheevi (P.I. 94760, U.S.S.R.) hybrid showing 3 univalents, 11 bivalents, and 1 trivalent.

Figure 2. Metaphase I in the dicoccoides (A. 11182, Turkey) X dicoccon (A. 11119, Yugoslavia) hybrid showing 14 bivalents.

Figure 3. Anaphase I in the dicoccoides (A. 11182, Turkey) X dicoccon (A. 11119, Yugoslavia) hybrid showing regular meiosis.

Figure 4. Metaphase in the dicoccoides (A. 11186, Turkey) X dicoccoides (A. 11147, Israel) hybrid showing 14 bivalents.

Figure 5. Metaphase I in the dicoccoides (A. 11189, Turkey) X dicoccoides (A. 11150, Israel) hybrid showing 11 univalents, 7 bivalents, and 1 trivalent.

Figure 6. Metaphase I in the timopheevi (P.I. 94760, U.S.S.R.) X dicoccon (A. 11119, Yugoslavia) hybrid showing 7 univalents, 9 bivalents, and 1 trivalent.

PLATE VIII

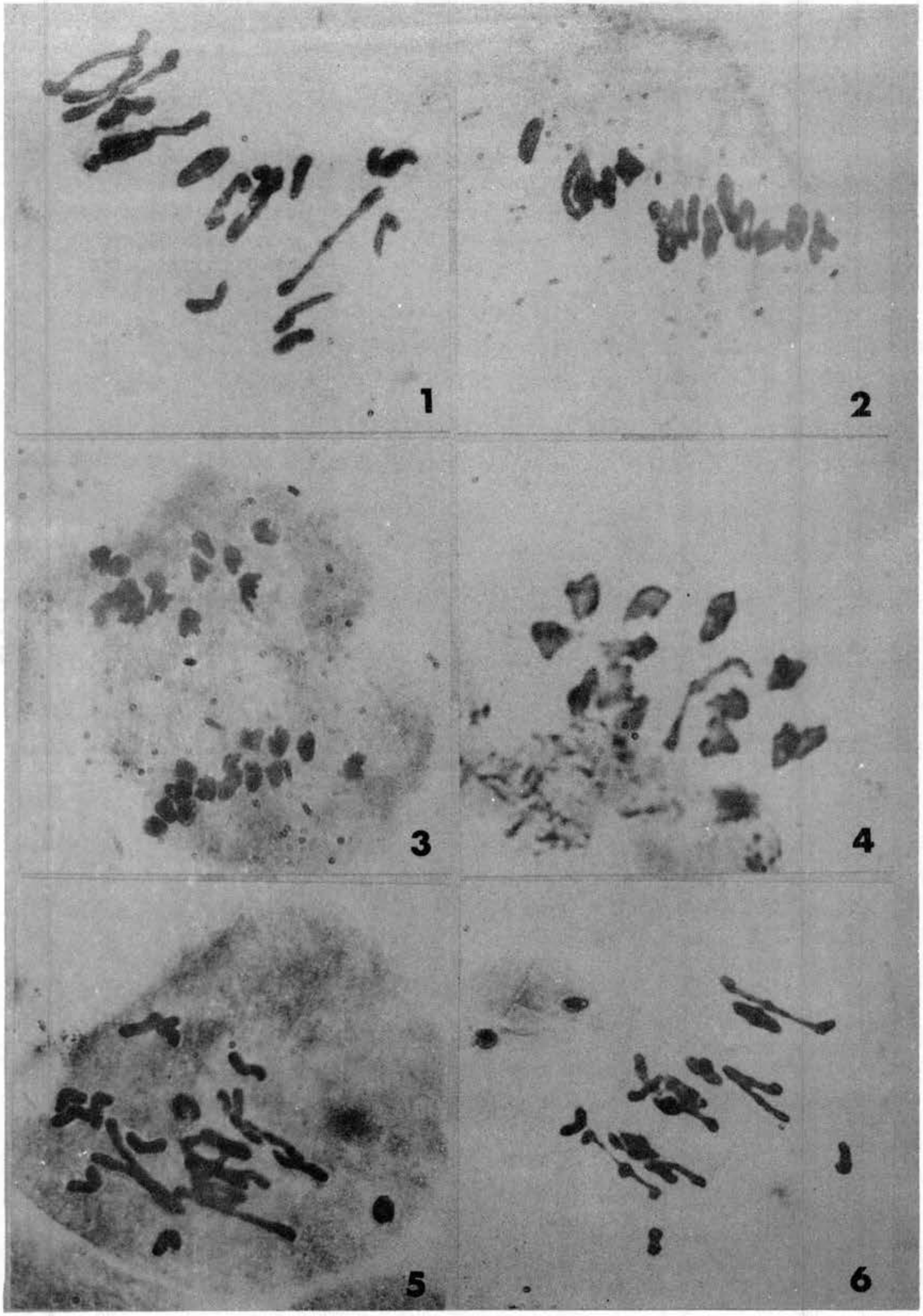


TABLE VIII

CYTOLOGY AND SEED SET DATA OF F_1 HYBRIDS OF TURKISH *DICOCCOIDES* ACCESSIONS WITH OTHER TETRAPLOID WHEATS

Cross	Chromosome association at meiotic metaphase I[1]					Fertility (% Seed Set)
	I	II	III	IV	V + VI	
dicoccoides (A.11182, Turkey) X *timopheevi* (P.I.94760, U.S.S.R.)	7.07 3-12	8.80 6-12	0.13 0-1	0.73 0-2	0	0
dicoccoides (A.11186, Turkey) X *timopheevi* (P.I.94760, U.S.S.R.)	9.13 3-16	7.40 6-11	0.20 0-1	0.87 0-2	0	0
dicoccoides (A.11187, Turkey) X *timopheevi* (P.I.94760, U.S.S.R.)	7.40 2-14	8.20 5-11	0.20 0-1	0.80 0-2	0.07 0-1	0
Average and range for (A.11182, A.11186, A.11187) with *timopheevi*	7.87 2-16	8.13 5-12	0.18 0-1	0.80 0-2	0.02 0-1	0
dicoccoides (A.11189, Turkey) X *timopheevi* (P.I.94760, U.S.S.R.)	0.40 0-2	13.20 12-14	0.13 0-1	0.20 0-1	0	4
dicoccoides (A.11191, Turkey) X *timopheevi* (P.I.94760, U.S.S.R.)	0.40 0-2	13.53 12-14	0	0.13 0-1	0	5
dicoccoides (A.11182, Turkey) X dicoccon (A.11119, Yugoslavia)	0	14.00 14	0	0	0	72
dicoccoides (A.11194, Turkey) X dicoccon (A.11119, Yugoslavia)	0	13.60 12-14	0	0.20 0-1	0	93
Average and range for (A.11182, A.11194) with dicoccon	0	13.80 12-14	0	0.10 0-1	0	83
dicoccoides (A.11189, Turkey) X dicoccon (P.I.94624, Iran)	5.60 1-10	9.93 8-12	0.20 0-1	0.40 0-1	0.07 0-1	0
dicoccoides (A.11191, Turkey) X dicoccon (P.I.12213, India)	0.47 0-4	13.53 12-14	0.07 0-1	0.07 0-1	0	8
dicoccoides (A.11182, Turkey) X turgidum	0	13.87 12-14	0	0.07 0-1	0	32
dicoccoides (A.11182, Turkey) X carthlicum (P.I.78812, Iran)	0	14.00 14	0	0	0	80
dicoccoides (A.11186, Turkey) X *dicoccoides* (A.11147, Israel)	0	14.00 14	0	0	0	85
dicoccoides (A.11186, Turkey) X *dicoccoides* (A.11150, Israel)	0	12.67 12-14	0	0.67 0-1	0	30
dicoccoides (A.11189, Turkey) X *dicoccoides* (A.11150, Israel)	8.73 5-14	7.67 5-11	0.13 0-1	0.80 0-3	0.07 0-1	0

[1]Average number and range of various configurations for 25 cells in each hybrid are listed. I = univalent; II = bivalent; III = trivalent; IV = quadrivalent; V + VI = pentavalents and hexavalents.

fertility in Israeli *dicoccoides* hybrids (Plate VIII, Figure 4).

Accession 11189 of *dicoccoides* from Turkey showed a different pattern of chromosome pairing and fertility in hybrids from that found in other Turkish wild emmers. It showed good chromosome pairing (13.2 bivalents, more than half closed) and low fertility (4% seed set) in hybrids with *timopheevi*. In hybrid with dicoccon this accession showed poor chromosome pairing (10 bivalents, mostly open) and complete sterility. With *dicoccoides* from Israel, it showed 8.7 bivalents (mostly open) and complete sterility. Cells with 5 to 14 univalents, 5 to 11 bivalents, 0 to 1 trivalents, and 0 to 3 quadrivalents were observed (Plate VIII, Figure 5). In cytological behaviour it resembled closely *timopheevi*.

The Turkish *dicoccoides* accession 11191 was different from the rest of Turkish *dicoccoides* accessions in cytological behaviour. It showed good chromosome pairing (14 bivalents, more than half closed) and some fertility (5% seed set) in hybrids with *timopheevi*. It also showed good chromosome pairing (14 bivalents, more than half open) and some fertility (8% seed set) in hybrids with dicoccon.

The chromosome association and fertility of F_1 hybrids of *timopheevi* with other tetraploid accessions is given in Table IX. The variety *timopheevi* showed poor chromosome pairing and complete sterility in hybrids with three Israeli *dicoccoides* accessions and three Turkish *dicoccoides* accessions (A. 11182, A. 11186, A. 11187) (Plate VII, Figures 1, 2, 3, 5, and 6; Plate VIII, Figure 1). In hybrids with *dicoccoides* accessions 11189 and 11191 from Turkey, it showed good chromosome pairing and some fertility. With three dicoccon accessions (A. 11119, A. 11218, P.I. 12213), *timopheevi* showed poor chromosome

TABLE IX

CYTOLOGY AND SEED SET DATA OF F_1 HYBRIDS OF TIMOPHEEVI ACCESSION WITH OTHER TETRAPLOID WHEATS

Cross	Chromosome association at meiotic metaphase I[1] I	II	III	IV	V + VI	Fertility (% seed set)
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11140, Israel)	6.12 4-10	9.07 8-10	0.25 0-1	0.75 0-2	0	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11147, Israel)	9.28 4-14	7.33 5-10	0.28 0-1	0.81 0-2	0	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11150, Israel)	5.93 2-8	6.47 4-9	1.00 0-2	1.53 2-3	0	0
Average and range for *timopheevi* with (A.11140, A.11147, A.11150)	7.11 4-14	7.62 4-10	0.51 0-2	1.03 0-3	0	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11182, Turkey)	7.07 3-12	8 80 6-12	0.13 0-1	0.73 0-2	0	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11186, Turkey)	9.13 3-16	7.40 6-11	0.20 0-1	0.87 0-2	0	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11187, Turkey)	7.40 2-14	8.20 5-11	0.20 0-1	0.80 0-2	0.07 0-1	0
Average and range for *timopheevi* with (A.11182, A.11186, A.11187)	7.87 2-16	8.13 5-12	0.18 0-1	0.80 0-2	0.02 0-1	0
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11189, Turkey)	0.40 0-2	13.20 12-14	0.13 0-1	0.20 0-1	0	4
timopheevi (P.I.94760, U.S.S.R.) X *dicoccoides* (A.11191, Turkey)	0.40 0-2	13.53 12-14	0	0.13 0-1	0	5
timopheevi (P.I.94760, U.S.S.R.) X dicoccon (A.11119, Yugoslavia)	4.80 2-8	9.27 6-13	0.13 0-1	1.07 0-2	0	0
timopheevi (P.I.94760, U.S.S.R.) X dicoccon (P.I.12213, India)	9.87 6-12	7.20 6-9	0	0.93 0-1	0	0
timopheevi (P.I.94760, U.S.S.R.) X dicoccon (A.11218, Ethiopia)	7.60 2-10	8.07 5-10	0.40 0-1	0.60 0-1	0.13 0-1	0
Average and range for *timopheevi* with (A.11119, A.11218, P.I.12213)	7.42 2-12	8.07 5-13	0.18 0-1	0.87 0-2	0.04 0-1	0
timopheevi (P.I.94760, U.S.S.R.) X turgidum	3.73 0-8	9.60 8-11	0.13 0-1	1.00 0-2	0.13 0-1	1
timopheevi (P.I.94760, U.S.S.R.) X carthlicum (P.I.78812, Iran)	5.40 0-10	9.20 7-12	0.07 7-12	1.00 0-2	0	1

[1]Average number and range of various configurations for 25 cells in each hybrid are listed. I = univalents; II = bivalents; III = trivalents; IV = quadrivalents; V + VI = pentavalents and hexavalents.

pairing and complete sterility. An average of 7.4 univalents, 8.0 bivalents (about half opened), 0.2 trivalents, and 0.9 quadrivalents were observed in these hybrids. Cells with 2 to 10 univalents, 5 to 10 bivalents, 0 to 1 trivalents, 0 to 2 quadrivalents, and 2 cells with a chain of 5 chromosome were observed (Plate VIII, Figure 6). In hybrids with turgidum and carthlicum timopheevi showed similar chromosome pairing and fertility. It showed an average of 4.6 univalents, 9.4 bivalents, 0.2 trivalents, 1.0 quadrivalents, and 1% seed set.

The fertility (% seed set) of all the parents and F_1 hybrids is given in Table X and XI respectively. The results showed good correlation with cytological data except in few cases.

A schematic representation of the hybridization range in the tetraploid wheats involved in this study is shown in Plate IX. This representation is based on the number of bivalents and fertility of F_1 hybrids evaluated here.

TABLE X

SELF FERTILITY (% SEED SET) OF ACCESSIONS

Accession	Number	Country	Florets	Seed	Fertility (% Seed Set)
dicoccoides	A. 11140	Israel	134	107	80
dicoccoides	A. 11147	Israel	284	213	75
dicoccoides	A. 11150	Israel	62	60	97
dicoccoides	A. 11153	Israel	76	50	66
dicoccoides	A. 11182	Turkey	128	61	48
dicoccoides	A. 11186	Turkey	194	172	89
dicoccoides	A. 11187	Turkey	182	137	75
dicoccoides	A. 11189	Turkey	114	70	61
dicoccoides	A. 11191	Turkey	128	94	73
dicoccoides	A. 11194	Turkey	90	59	66
timopheevi	P.I. 94760	U.S.S.R.	96	89	93
dicoccon	A. 11218	Ethiopia	176	128	73
dicoccon	A. 11221	Ethiopia	200	150	75
dicoccon	P.I. 58788-2	Ethiopia	60	49	82
dicoccon	P.I. 12213	India	62	35	56
dicoccon	P.I. 94624	Iran	164	125	76
dicoccon	P.I. 56235	U.S.S.R.	229	129	56
dicoccon	A. 11119	Yugoslavia	336	257	76
dicoccon	P.I. 221398	Yugoslavia	97	92	95
dicoccon	P.I. 221403	Yugoslavia	98	80	82
turgidum	--	--	--	--	good
carthlicum	P.I. 78812	Iran	136	79	58

TABLE XI

SELF FERTILITY (% SEED SET) OF F_1 HYBRIDS

Cross	Florets	Seed	Fertility (% Seed Set)
dicoccoides (A. 11140) X timopheevi (P.I. 94760)	178	0	0
dicoccoides (A. 11147) X timopheevi (P.I. 94760)	328	0	0
dicoccoides (A. 11150) X timopheevi (P.I. 94760)	240	0	0
dicoccoides (A. 11153) X timopheevi (P.I. 94760)	390	0	0
dicoccoides (A. 11182) X timopheevi (P.I. 94760)	416	0	0
dicoccoides (A. 11186) X timopheevi (P.I. 94760)	410	0	0
dicoccoides (A. 11187) X timopheevi (P.I. 94760)	216	0	0
dicoccoides (A. 11189) X timopheevi (P.I. 94760)	186	8	4
dicoccoides (A. 11191) X timopheevi (P.I. 94760)	276	13	5
dicoccoides (A. 11194) X timopheevi (P.I. 94760)	58	0	0
dicoccoides (A. 11140) X dicoccon (A. 11119)	78	64	82
dicoccoides (A. 11140) X dicoccon (A. 11221)	132	34	26
dicoccoides (A. 11147) X dicoccon (P.I. 12213)	112	30	27
dicoccoides (A. 11150) X dicoccon (P.I. 12213)	118	31	26
dicoccoides (A. 11150) X dicoccon (P.I. 94624)	52	19	37
dicoccoides (A. 11150) X dicoccon (A. 11218)	154	41	27
dicoccoides (A. 11153) X dicoccon (A. 11119)	152	33	22
dicoccoides (A. 11153) X dicoccon (A. 11221)	192	69	36
dicoccoides (A. 11182) X dicoccon (A. 11119)	82	59	72
dicoccoides (A. 11182) X dicoccon (P.I. 12213)	66	3	5
dicoccoides (A. 11182) X dicoccon (P.I. 94624)	22	8	36
dicoccoides (A. 11186) X dicoccon (A. 11119)	188	100	53
dicoccoides (A. 11186) X dicoccon (A. 11221)	20	17	85
dicoccoides (A. 11187) X dicoccon (A. 11119)	48	25	52
dicoccoides (A. 11189) X dicoccon (A. 11119)	138	0	0
dicoccoides (A. 11189) X dicoccon (A. 11218)	128	0	0
dicoccoides (A. 11189) X dicoccon (P.I. 94624)	172	0	0
dicoccoides (A. 11191) X dicoccon (A. 11221)	132	10	8
dicoccoides (A. 11194) X dicoccon (A. 11119)	74	69	93
dicoccoides (A. 11194) X dicoccon (P.I. 94624)	117	108	92
dicoccoides (A. 11194) X dicoccon (P.I. 221398)	70	60	97
dicoccoides (A. 11140) X turgidum	122	98	80
dicoccoides (A. 11153) X turgidum	80	65	81
dicoccoides (A. 11182) X turgidum	186	60	32
dicoccoides (A. 11186) X turgidum	204	135	66
dicoccoides (A. 11187) X turgidum	216	162	75
dicoccoides (A. 11189) X turgidum	196	0	0
dicoccoides (A. 11150) X carthlicum (P.I. 78812)	112	2	2

TABLE XI (CONTINUED)

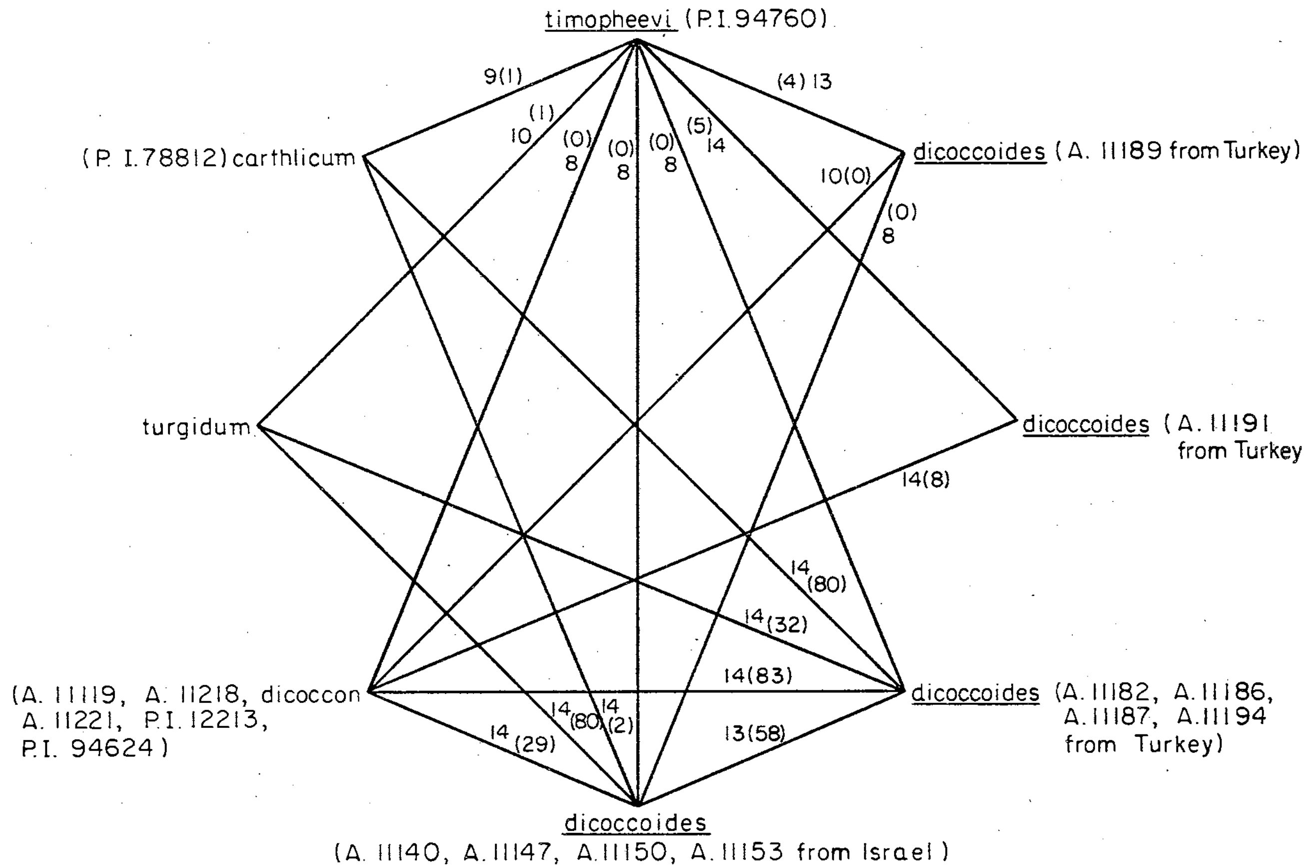
Cross	Florets	Seed	Fertility (% Seed Set)
dicoccoides (A. 11153) X carthlicum (P.I. 78812)	36	0	0
dicoccoides (A. 11182) X carthlicum (P.I. 78812)	16	14	88
dicoccoides (A. 11186) X carthlicum (P.I. 78812)	58	48	83
dicoccoides (A. 11189) X carthlicum (P.I. 78812)	220	0	0
timopheevi (P.I. 94760) X dicoccon (A. 11119)	86	0	0
timopheevi (P.I. 94760) X dicoccon (A. 11218)	160	0	0
timopheevi (P.I. 94760) X dicoccon (A. 11221)	62	0	0
timopheevi (P.I. 94760) X dicoccon (P.I.58788-2)	54	0	0
timopheevi (P.I. 94760) X dicoccon (P.I. 94624)	226	0	0
timopheevi (P.I. 94760) X dicoccon (P.I. 221403)	184	0	0
timopheevi (P.I. 94760) X turgidum	136	1	1
timopheevi (P.I. 94760) X carthlicum (P.I. 78812)	152	1	1

PLATE IX

HYBRIDIZATION RANGE IN TETRAPLOID WHEAT ACCESSIONS INVOLVED IN THIS STUDY

PLATE IX

HYBRIDIZATION RANGE IN TETRAPLOID WHEAT ACCESSIONS INVOLVED IN THIS STUDY



O - Number of bivalents in meiotic metaphase I of F_1 hybrids.

(O) - % seed set in F_1 hybrids.

CHAPTER V

DISCUSSION

The morphological data presented here supports the thesis of Harlan and Zohary (11) that there are two main races of wild emmer. The Israeli accessions could be readily separated from the Turkish accessions on the basis of the following characters: stem thickness, leaf width, leaf color, spike compactness, spikelet number per spike, rachis internode length and width, and pubescence at the rachis internode edge. In comparison with the Turkish dicoccoides the Israeli accessions have more robust plants, thicker stems, and wider leaves, which are pale green in color. Also they have lax heads with fewer spikelets, longer and wider rachis internodes with dense hairs on the edge. The morphological differences can be supplemented with different ecological nature of the two races. The Israeli accessions are early in maturity, less winterhardy, and have some spring growth habit whereas the Turkish accessions are late in maturity, more winterhardy, and have winter growth habit.

The geographical distribution of dicoccoides as presented by Harlan and Zohary (11) shows that there is a significant discontinuity between the northernmost outpost in Lebanon for the Palestine race and the southernmost location of the Turkish-Iraqi race in Turkey. The region does not seem to be climatically suitable for wild emmer at the present time. The area is too low, hot and dry (10).

Probably some time back wild emmer had continuous distribution over this area but two races apparently have been separated a long time (10). This long standing geographic isolation resulted in two morphologically distinct races with different ecological adaptations. It seems probable that introgression of some populations of Turkish wild emmers with wild diploids modified their morphology.

Some characters are common for both Israeli and Turkish wild emmers. With regard to glume beaks and shoulder shape, glume pubescence, number of veins in glume and lemma, and lemma awn length, forms with different combinations are found in accessions from Israel as well as Turkey. This indicates all these accessions are related. The Turkish accessions appear to be very close to wild einkorn wheat (diploid) in plant size and morphology. The sympatric distribution of these diploid wheats with wild emmer seems to have resulted in active introgression between diploids and tetraploids, as they show similarity in many characters (10).

Percival (22, 23) reported the presence of more than two vascular bundles in the coleoptile of wild emmer. Present results contradict this inasmuch as both Israeli and Turkish wild emmer accessions studied here have only two. Three to five vascular bundles were observed in the Ethiopian and Indian emmers, while all other emmers had only two. This part is in accordance with Percival's (22, 23) results. It is difficult to explain the deviation of Ethiopian and Indian emmers from all other wheat groups for this character. It is probably that mutation for high number of vascular bundles took place in these emmers after they were separated from the others.

The cytogenetic relationships and seed set data show a pattern of variation in wild emmer different from that based on distribution, ecology, and morphology. Except for two accessions (A. 11189 and A. 11191 from Turkey) all wild emmers from Israel and Turkey show similar chromosome pairing and fertility in hybrids with other tetraploids. They show good pairing and fertility in hybrids with dicoccon, turgidum, and carthlicum, while showing poor chromosome pairing and sterility in hybrids with timopheevi. There was good pairing and seed set in intercrosses between the two groups of dicoccoides accessions. Although the Israeli wild emmer accessions are different from the four Turkish wild emmer accessions in their morphology and ecological adaptations, they were not cytogenetically different from four of the Turkish accessions (A. 11182, A. 11186, A. 11187, and A. 11194).

The wild emmer accession 11189 from Turkey showed close cytogenetic relationships with timopheevi. The hybrid had 14 bivalents and low fertility (4% seed set). Sterility in hybrids even after normal chromosome pairing could be due to cryptic structural hybridity (34). This accession, like timopheevi, shows poor chromosome pairing and sterility in hybrids with dicoccon and Israeli dicoccoides. Morphological data shows that this accession has pubescent leaves which is typical of timopheevi and not found in any other Israeli or the four Turkish accessions similar to the Israeli accessions in pairing relationships. This is interpreted to mean that accession 11189 of Turkish dicoccoides represents a population which has undergone differentiation in its cytology to the extent it is close to timopheevi and different from other dicoccoides.

The accession 11191 is of special interest because of its similarity in apparent normal chromosome pairing in hybrids with both timopheevi and dicoccon. It forms 14 bivalents with both but shows low seed set with both. This accession also has pubescent leaves. This accession 11191 is somewhat similar in cytological behaviour to the dicoccoides accession 11189 and timopheevi as well as other dicoccoides and dicoccon accessions.

It is difficult to explain the cytological behaviour of accessions 11189 and 11191 which differ from other wild emmer accessions studied. These two accessions were collected from an area close to the other four Turkish dicoccoides accessions (Plate II). No geographical or ecological barriers seem to exist between these accessions (11189 and 11191) and the other four Turkish dicoccoides accessions (11182, 11186, 11187, and 11194). The leaf pubescence of these two accessions is typical of timopheevi but not found in the other wild emmer accessions. It is probable that introgression of wild diploid wheats and possibly other wheats resulted in chromosomal differentiation within some of the Turkish wild emmer populations. Chromosomal rearrangement might have taken place at the same time. The variety timopheevi could have been derived from these cytologically differentiated Turkish wild emmer populations. The accessions 11189 and 11191 could be the representative genotypes of these cytologically differentiated Turkish dicoccoides populations.

The present results support the suggestion of Sachs (26) that chromosomal differentiation had taken place in wild emmer. Wagenaar (38) ruled out the possibility of genetic mutations as well as that specific translocations arising one at a time from the original populations under the influence of selection and the emergence of stable genotype, as resulting in gradual origin of timopheevi from *dicoccoides*. He presumed that since genotypes intermediate between *timopheevi* and *dicoccoides* had not been reported they did not exist. Under Wagenaar's hypothesis, accession 11191 is a cytogenetic intermediate and would seem to be the necessary connecting link. Wagenaar further suggests that at least two genes are involved in the meiotic chromosome pairing of hybrids of *timopheevi* with *dicoccoides* and other tetraploids. He assumes that *timopheevi* is homozygous for these genes, which in heterozygous condition cause asynapsis in *timopheevi* hybrids. If this is true, it is difficult to explain the perfect pairing of accession 11191 with *timopheevi* as well as dicoccon.

Feldman (7) in his studies found it difficult to explain how these asynapsis causing genes, if present, could effect only the pairing of the chromosomes of B genome and why they have a different effect on different chromosome arms. Mukade (21) obtained a hexaploid wheat which had one pair of chromosomes derived from *timopheevi*. Even in the genetic background of a hexaploid wheat, *timopheevi* chromosomes showed little pairing with the corresponding chromosomes of *T. aestivum*. Thus it is difficult to explain the meiotic irregularities in *timopheevi* hybrids on the basis of Wagenaar's proposed genetic asynaptic system in *timopheevi*. It seems that chromosomal differentiation in the second (B) genome of *timopheevi* is the cause of meiotic irregularities in hybrids. Zohary and Feldman (43) reported the presence of a modified genome by the side of an unmodified basic genome in polyploid wheats. The B genome may be the cause of the cytogenetic discontinuity, and the introgression with A genome may have caused the morphological discontinuity (10).

The genome constitution of *timopheevi* has been interpreted differently at different times. In the present study with _timopheevi_ hybrids, cells with 8 to 10 bivalents and occasionally with 11 and rarely 12 bivalents were observed. This shows there is partial homology between the chromosomes of the second genome of _timopheevi_ and the chromosomes of B genome in other tetraploids. Kostoff (17), Love (19), Sachs (26), Wagenaar (37, 38), and Feldman (7) suggested that the second genome of _timopheevi_ is partially homologous to the B genome in the other tetraploid wheats. As chromosomal races similar to _timopheevi_ are observed in _dicoccoides_, _timopheevi_ could be given a genome formula similar to that of wild emmer.

The cultivar, carthlicum, gave good chromosome pairing with Israeli (Accession 11150) and Turkish (Accession 11182) wild emmers, but seed set was only 2% in Israeli hybrids while it was 80% in Turkish wild emmer hybrids. This indicates that carthlicum is closer to Turkish wild emmer than Israeli wild emmer. The cultivar, carthlicum, is probably a race sorted out of introgressing populations involving Turkish wild emmers with other wheats (10). Morris and Sears (20) proposed that carthlicum originated through hybridization of some tetraploid wheat with a hexaploid of the aestivum group.

The cultivar, dicoccon, formed fertile hybrids and good seed set with Israeli and four (A. 11182, A. 11186, A. 11187, and A. 11194) Turkish wild emmers. Cytological and seed set data of the F_1 hybrids show that emmer is close to the Israeli and four Turkish _dicoccoides_ accessions. Vavilov (35) doubted the origin of emmer from _dicoccoides_. However, the reports of Schiemann (30, 31, 32, 33), Helbaek (12, 13), and Harlan and Zohary (11) strongly suggest that _dicoccoides_ is the progenitor of cultivated emmer wheat. Cytogenetic results from the present investigation suggest that either Israeli or Turkish wild emmers or both could have been the progenitors of cultivated emmer.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The racial pattern in wild emmer wheat (Triticum turgidum L. em. var. dicoccoides /Körn/ Bowden) and its relationship to timopheevi, dicoccon, turgidum and carthlicum was studied. A total of 22 tetraploid wheat accessions, including four Israeli and six Turkish wild emmer, one timopheevi, nine dicoccon, one turgidum and one carthlicum were used in the study. The herbarium specimens were made for all the accessions and 21 qualitative and quantitative morphological characters of these accessions were evaluated by using Anderson's pictorialized scatter diagrams. The number of the vascular bundles in the coleoptile of each accession was also studied. In order to investigate the cytogenetic relationships, crosses were made in various combinations between the Israeli dicoccoides, the Turkish dicoccoides, timopheevi, dicoccon, turgidum and carthlicum accessions. The F_1 hybrids were grown in the greenhouse and chromosome pairing during meiotic metaphase I was examined. The F_1 hybrids were selfed by bagging and fertility based on the seed set was recorded. Results from the morphological, anatomical, and cytogenetical studies were analyzed to establish possible relationships among the accessions used in the study.

Morphological data for certain characters showed differences between Israeli and Turkish dicoccoides. The Israeli accessions were characterized by lax heads with few spikelets, and long and wide rachis internodes with dense hairs. The Israeli group was robust with thick stems, wide leaves, pale green in color, early in maturity, less winterhardy, and showed some spring growth habit. The Turkish accessions were characterized by compact heads with large number of spikelets, and short and narrow rachis internodes with sparse hairs. The Turkish group was small with thin stems, narrow leaves, dark green in color, late in maturity, more winterhardy, and showed winter growth habit. Anderson's pictorialized scatter diagrams showed a separation of Israeli and Turkish dicoccoides groups based on the ratios of internode length, internode width, spikelets per spike, and first lemma length. Also these ratios indicated that timopheevi was closer to Turkish than Israeli wild emmer. Of all dicoccoides accessions only two (Turkish accessions 11189 and 11191) had pubescent leaves which is characteristic of timopheevi. There was no difference in the number of vascular bundles between two groups of dicoccoides accessions.

Cytological data and fertility of F_1 hybrids showed a variation pattern different to the one based on morphology. The wild emmers from Israel were cytogenetically uniform, and showed poor chromosome pairing and sterility in hybrids with timopheevi. They showed good pairing and fertility in hybrids with dicoccon, turgidum, and carthlicum. Cytogenetic differentiation was observed among the Turkish wild emmer accessions. One accession (A. 11189) showed close cytogenetic affinity to timopheevi; four accessions were similar in pairing relationships to Israeli wild emmer, turgidum, and carthlicum accessions; and one accession (11191) appears to be cytogenetically intermediate between timopheevi and dicoccon.

Based on the results of this study, it is possible that either Israeli or Turkish wild emmers or both could have been the progenitors of cultivated emmer, turgidum, and carthlicum. The variety _timopheevi_ might have an origin similar to that of Turkish wild emmer accession 11189. The genome formula of _timopheevi_ may be given similar to that of wild emmer. The treatment of all tetraploid wheats under the same species _T. turgidum_ by Bowden (3) seemed to be in accordance with the evidence from the present investigation. More collections of wild emmer from southeast Turkey should be studied to substantiate the present findings.

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APPENDIX

TABLE XII

QUALITATIVE MORPHOLOGICAL CHARACTERS OF DICOCCOIDES AND TIMOPHEEVI ACCESSIONS[1]

Accession	Number	Country	Leaf Pubescence[2]		Pubescence on Rachis Internode Edge			Pubescence at Base of Spikelet			Number of Fertile Florets for Spikelet		
			-	+	-	+	++	-	+	++	2	3	4
dicoccoides	A. 11140	Israel	3	0	0	6	0	0	6	0	6	0	0
dicoccoides	A. 11147	Israel	3	0	0	0	6	0	0	6	6	0	0
dicoccoides	A. 11150	Israel	3	0	0	0	6	0	0	6	6	0	0
dicoccoides	A. 11153	Israel	3	0	0	0	6	0	0	6	6	0	0
Israeli dicoccoides total			12	0	0	6	18	0	6	18	24	0	0
dicoccoides	A. 11182	Turkey	3	0	0	1	5	0	6	0	6	0	0
dicoccoides	A. 11186	Turkey	3	0	0	5	1	0	6	0	6	0	0
dicoccoides	A. 11187	Turkey	3	0	0	6	0	0	6	0	6	0	0
dicoccoides	A. 11189	Turkey	0	3	0	6	0	0	6	0	6	0	0
dicoccoides	A. 11191	Turkey	0	3	0	6	0	0	6	0	6	0	0
dicoccoides	A. 11194	Turkey	3	0	0	6	0	0	6	0	6	0	0
Turkish dicoccoides total			12	6	0	30	6	0	36	0	36	0	0
timopheevi	P.I. 94760	U.S.S.R.	0	3	0	6	0	0	6	0	6	0	0

[1]Frequency of spikelets for each character in each accession was given. Units of description were given in Table II.

[2]For this character number of plants scored was given.

TABLE XII (CONTINUED)

Accession	Number	Country	Glume: Pubescence -	Pubescence +	Pubescence ++	Texture of Margins: Thin	Texture of Margins: Thick	Number of Veins: Narrow Side 1	Narrow Side 2	Broad Side 5	Broad Side 6	Broad Side 7	Broad Side 8	Broad Side 9
dicoccoides	A. 11140	Israel	6	0	0	5	1	6	0	1	5	0	0	0
dicoccoides	A. 11147	Israel	1	0	5	0	6	3	3	0	1	1	3	1
dicoccoides	A. 11150	Israel	6	0	0	2	4	2	4	0	0	4	2	0
dicoccoides	A. 11153	Israel	0	0	6	0	6	6	0	0	6	0	0	0
Israeli dicoccoides total			13	0	11	7	17	17	7	1	12	5	5	1
dicoccoides	A. 11182	Turkey	6	0	0	0	6	6	0	0	6	0	0	0
dicoccoides	A. 11186	Turkey	6	0	0	3	3	5	1	0	6	0	0	0
dicoccoides	A. 11187	Turkey	6	0	0	6	0	6	0	0	3	3	0	0
dicoccoides	A. 11189	Turkey	0	6	0	6	0	6	0	0	0	4	2	0
dicoccoides	A. 11191	Turkey	5	1	0	5	1	5	1	1	2	3	0	0
dicoccoides	A. 11194	Turkey	6	0	0	6	0	6	0	0	4	2	0	0
Turkish dicoccoides total			29	7	0	26	10	34	2	1	21	12	2	0
timopheevi	P.I. 94760	U.S.S.R.	0	6	0	0	6	6	0	0	0	6	0	0

TABLE XII (CONTINUED)

Accession	Number	Country	Glume: Beak Shape: Obtuse	Glume: Beak Shape: Acute	Glume: Beak Shape: Acum.	Glume: Shoulder Shape: Round	Glume: Shoulder Shape: Square	Glume: Shoulder Shape: Elev.	Glume: Shoulder Shape: Apic.	1st Lemma: Pubescence: -	1st Lemma: Pubescence: +	1st Lemma: Pubescence: ++	1st Lemma: Veins Number: 9	1st Lemma: Veins Number: 10	1st Lemma: Veins Number: 11	1st Lemma: Veins Number: 12	1st Lemma: Veins Number: 13	1st Lemma: Veins Number: 14	1st Lemma: Veins Number: 15
dicoccoides	A. 11140	Israel	0	6	0	0	3	3	0	6	0	0	0	0	5	1	0	0	0
dicoccoides	A. 11147	Israel	0	6	0	0	2	4	0	1	0	5	1	0	4	1	0	0	0
dicoccoides	A. 11150	Israel	0	6	0	0	0	5	1	6	0	0	0	2	2	2	0	0	0
dicoccoides	A. 11153	Israel	0	2	4	0	0	0	6	0	0	6	2	2	2	0	0	0	0
Israeli dicoccoides total			0	20	4	0	5	12	7	13	0	11	3	4	13	4	0	0	0
dicoccoides	A. 11182	Turkey	0	6	0	0	0	0	6	6	0	0	0	0	5	0	1	0	0
dicoccoides	A. 11186	Turkey	1	5	0	3	0	3	0	6	0	0	1	0	5	0	0	0	0
dicoccoides	A. 11187	Turkey	0	3	3	0	0	1	5	6	0	0	0	0	6	0	0	0	0
dicoccoides	A. 11189	Turkey	4	2	0	0	0	4	2	0	6	0	0	0	3	0	1	1	1
dicoccoides	A. 11191	Turkey	0	1	5	0	1	0	5	6	0	0	5	1	0	0	0	0	0
dicoccoides	A. 11194	Turkey	1	5	0	0	5	1	0	6	0	0	6	0	0	0	0	0	0
Turkish dicoccoides total			6	22	8	3	6	9	18	30	6	0	12	1	19	0	2	1	1
timopheevi	P.I. 94760	U.S.S.R.	0	1	5	0	0	0	6	0	6	0	0	0	2	0	1	2	1

TABLE XIII

QUANTITATIVE MORPHOLOGICAL CHARACTERS OF DICOCCOIDES AND TIMOPHEEVI ACCESSIONS[1]

Accession	Number	Country	Glume		1st Lemma	2nd Lemma	
			Length (cm)	Width (cm)	Awn Length (cm)	Awn Length (cm)	Lemma Length (cm)
dicoccoides	A. 11140	Israel	1.06 0.97-1.11	0.25 0.23-0.31	13.4 11.0-15.1	12.4 9.5-16.3	1.18 1.03-1.28
dicoccoides	A. 11147	Israel	1.62 1.57-1.70	0.34 0.28-0.38	17.9 16.7-20.0	18.0 16.9-19.6	1.48 1.40-1.58
dicoccoides	A. 11150	Israel	1.54 1.49-1.61	0.30 0.24-0.37	16.5 13.6-18.0	16.8 13.6-19.1	1.45 1.40-1.48
dicoccoides	A. 11153	Israel	1.39 1.33-1.46	0.26 0.21-0.29	12.2 10.8-13.0	12.2 11.0-13.6	1.28 1.26-1.32
Israeli dicoccoides average and range			1.40 0.97-1.70	0.29 0.21-0.38	15.0 10.8-20.0	14.9 9.5-19.6	1.35 1.03-1.58
dicoccoides	A. 11182	Turkey	1.27 1.22-1.32	0.28 0.26-0.33	13.5 12.7-14.5	13.1 12.4-14.2	1.45 1.42-1.50
dicoccoides	A. 11186	Turkey	1.16 1.05-1.20	0.26 0.20-0.32	12.8 10.7-14.7	5.0 2.6-8.5	1.29 1.18-1.35
dicoccoides	A. 11187	Turkey	1.38 1.30-1.45	0.29 0.27-0.30	16.5 15.6-18.9	15.2 14.0-16.3	1.58 1.50-1.67
dicoccoides	A. 11189	Turkey	1.05 1.02-1.08	0.23 0.17-0.28	14.4 13.4-16.2	13.1 12.0-14.4	1.30 1.20-1.35
dicoccoides	A. 11191	Turkey	1.27 1.20-1.35	0.26 0.20-0.28	13.1 12.0-14.6	6.8 3.8-9.8	1.44 1.25-1.53
dicoccoides	A. 11194	Turkey	1.05 1.00-1.12	0.25 0.19-0.28	12.2 10.9-14.3	9.5 7.8-13.0	1.27 1.15-1.40
Turkish dicoccoides average and range			1.20 1.00-1.45	0.26 0.17-0.33	13.8 1.07-18.9	10.5 2.6-16.3	1.39 1.15-1.67
timopheevi	P.I. 94760	U.S.S.R.	1.05 1.00-1.16	0.30 0.28-0.32	7.8 6.2-8.4	7.9 6.1-9.1	1.20 1.15-1.33

[1]Average and range of six spikelets for each character in each accession were given.

TABLE XIV

QUALITATIVE MORPHOLOGICAL CHARACTERS OF DICOCCON, TURGIDUM AND CARTHLICUM ACCESSIONS[1]

Accession	Number	Country	Leaf Pubescence[2]		Pubescence on Rachis Internode Edge			Pubescence at Base of Spikelet			Number of Fertile Florets for Spikelet		
			-	+	-	+	++	-	+	++	2	3	4
dicoccon	P.I. 58788-2	Ethiopia	3	0	4	2	0	5	1	0	6	0	0
dicoccon	A. 11218	Ethiopia	3	0	6	0	0	6	0	0	6	0	0
dicoccon	A. 11221	Ethiopia	3	0	1	5	0	6	0	0	6	0	0
dicoccon	P.I. 12213	India	1	2	1	5	0	6	0	0	6	0	0
dicoccon	P.I. 94624	Iran	0	3	0	6	0	1	5	0	6	0	0
dicoccon	P.I. 56235	U.S.S.R.	3	0	0	6	0	6	0	0	6	0	0
dicoccon	P.I. 221398	Yugoslavia	3	0	5	1	0	5	1	0	6	0	0
dicoccon	P.I. 221403	Yugoslavia	3	0	0	6	0	0	6	0	5	1	0
dicoccon	A. 11119	Yugoslavia	1	2	5	1	0	6	0	0	6	0	0
dicoccon accessions total			20	7	22	32	0	41	13	0	53	1	0
turgidum[3]	--	unknown	3	0	2	2	0	4	0	0	0	2	2
carthlicum	P.I. 78812	Iran	3	0	6	0	0	6	0	0	2	4	0

[1]Frequency of spikelets for each character in each accession was given. Units of description were given in Table II.

[2]For this character number of plants scored was given.

[3]For this accession only 4 spikelets were observed.

TABLE XIV (CONTINUED)

Accession	Number	Country	Glume: Pubescence -	Pubescence +	Pubescence ++	Texture of Margins: Thin	Texture of Margins: Thick	Number of Veins, Narrow Side: 1	Narrow Side: 2	Narrow Side: 3	Narrow Side: 4	Broad Side: 5	Broad Side: 6	Broad Side: 7
dicoccon	P.I. 58788-2	Ethiopia	6	0	0	6	0	5	1	0	0	0	4	2
dicoccon	A. 11218	Ethiopia	6	0	0	6	0	6	0	0	0	0	6	0
dicoccon	A. 11221	Ethiopia	6	0	0	6	0	6	0	0	0	0	6	0
dicoccon	P.I. 12213	India	6	0	0	5	1	6	0	0	0	0	5	1
dicoccon	P.I. 94624	Iran	0	6	0	5	1	6	0	0	0	0	6	0
dicoccon	P.I. 56235	U.S.S.R.	6	0	0	6	0	6	0	0	0	0	6	0
dicoccon	P.I. 221398	Yugoslavia	1	5	0	4	2	2	4	0	0	2	4	0
dicoccon	P.I. 221403	Yugoslavia	0	5	1	5	1	0	4	2	0	0	6	0
dicoccon	A. 11119	Yugoslavia	6	0	0	5	1	0	6	0	0	5	1	0
dicoccon accessions total			37	16	1	48	6	37	15	2	0	7	44	3
turgidum[3]	--	unknown	0	4	0	0	4	2	2	0	0	2	2	0
carthlicum	P.I. 78812	Iran	0	6	0	0	6	0	5	0	1	0	5	1

TABLE XIV. (CONTINUED)

Accession	Number	Country	Glume: Beak Shape: Obtuse	Acute	Acum.	Glume: Shoulder Shape: Want.	Obliq.	Rnd.	Squa.	Elev.	1st Lemma: Pubescence: -	+	++	1st Lemma: Veins Number: 10	11	12	13	14	15	16	17
dicoccon	P.I. 58788-2	Ethiopia	5	1	0	0	0	0	5	1	6	0	0	0	5	0	1	0	0	0	0
dicoccon	A. 11218	Ethiopia	0	6	0	0	0	0	1	5	6	0	0	0	0	1	5	0	0	0	0
dicoccon	A. 11221	Ethiopia	0	6	0	0	0	0	0	6	6	0	0	1	3	1	1	0	0	0	0
dicoccon	P.I. 12213	India	0	6	0	0	0	0	0	6	6	0	0	0	1	0	5	0	0	0	0
dicoccon	P.I. 94624	Iran	0	6	0	0	5	0	1	0	0	6	0	0	0	1	3	1	0	0	1
dicoccon	P.I. 56235	U.S.S.R.	0	5	1	0	3	0	0	3	6	0	0	0	0	0	3	0	3	0	0
dicoccon	P.I. 221398	Yugoslavia	0	6	0	0	4	0	0	2	1	5	0	0	0	2	2	1	1	0	0
dicoccon	P.I. 221403	Yugoslavia	0	3	3	0	0	1	0	5	0	6	0	0	0	0	5	0	0	1	0
dicoccon	A. 11119	Yugoslavia	1	5	0	0	4	0	0	2	6	0	0	0	3	0	3	0	0	0	0
dicoccon accessions total			6	44	4	0	16	1	7	30	37	17	0	1	12	5	28	2	4	1	1
turgidum[3]	--	unknown	0	2	2	3	1	0	0	0	0	4	0	1	2	0	0	1	0	0	0
carthlicum	P.I. 78812	Iran	Modified to awn			Modified to awn					2	4	0	0	4	2	0	0	0	0	0

TABLE XV

QUANTITATIVE MORPHOLOGICAL CHARACTERS OF DICOCCON, TURGIDUM AND CARTHLICUM ACCESSIONS[1]

Accession	Number	Country	Spikelets for Spike (Number)	Rachis Internode		Glume	
				Length (cm)	Width (cm)	Length (cm)	Width (cm)
dicoccon	P.I. 58788-2	Ethiopia	20.2 19-22	0.36 0.29-0.45	0.25 0.23-0.27	1.04 0.93-1.17	0.30 0.26-0.33
dicoccon	A. 11218	Ethiopia	23.2 21-26	0.38 0.36-0.39	0.27 0.25-0.30	1.19 1.00-1.31	0.31 0.26-0.34
dicoccon	A. 11221	Ethiopia	20.8 19-23	0.34 0.26-0.47	0.24 0.21-0.28	1.07 0.96-1.15	0.29 0.28-0.30
dicoccon	P.I. 12213	India	20.2 16-27	0.39 0.35-0.45	0.22 0.20-0.26	0.96 0.90-1.05	0.27 0.23-0.30
dicoccon	P.I. 94624	Iran	14.7 12-18	0.33 0.31-0.37	0.20 0.19-0.23	1.01 0.94-1.10	0.31 0.27-0.36
dicoccon	P.I. 56235	U.S.S.R.	18.8 17-21	0.40 0.36-0.44	0.21 0.18-0.26	1.15 1.03-1.25	0.29 0.25-0.35
dicoccon	P.I. 221398	Yugoslavia	18.2 14-23	0.31 0.24-0.39	0.21 0.18-0.22	1.05 0.93-1.10	0.31 0.21-0.40
dicoccon	P.I. 221403	Yugoslavia	23.7 17-25	0.37 0.30-0.40	0.25 0.22-0.29	1.14 1.03-1.24	0.32 0.30-0.38
dicoccon	A. 11119	Yugoslavia	22 19-25	0.32 0.22-0.40	0.15 0.11-0.20	1.03 0.95-1.18	0.24 0.20-0.27
dicoccon accessions total			20.2 12-27	0.36 0.22-0.47	0.22 0.18-0.30	1.07 0.90-1.31	0.29 0.20-0.40
turgidum[2]	--	unknown	Above 30	0.49 0.42-0.60	0.26 0.23-0.28	0.78 0.71-0.90	0.35 0.22-0.48
carthlicum	P.I. 78812	Iran	20.6 18-23	0.50 0.42-0.60	0.16 0.13-0.17	1.22 1.03-1.50	0.34 0.27-0.40

[1]Average and range of six spikelets for each character in each accession were given.

[2]For this accession only four spikelets average and range was given.

TABLE XV (CONTINUED)

Accession	Number	Country	1st Lemma		2nd Lemma	
			Awn Length (cm)	Lemma Length (cm)	Awn Length (cm)	Lemma Length (cm)
dicoccon	P.I. 58788-2	Ethiopia	13.0 11.9-13.8	1.08 0.99-1.17	12.3 10.6-13.2	1.12 1.01-1.20
dicoccon	A. 11218	Ethiopia	14.2 11.5-16.1	1.16 1.05-1.30	12.9 11.0-15.1	1.16 1.08-1.28
dicoccon	A. 11221	Ethiopia	13.0 10.1-15.1	1.10 1.00-1.25	12.1 9.1-13.8	1.09 1.00-1.16
dicoccon	P.I. 12213	India	11.2 7.8-15.7	1.06 1.02-1.11	10.2 8.6-12.1	1.11 0.73-0.87
dicoccon	P.I. 94624	Iran	13.0 10.8-14.5	1.03 0.98-1.06	12.1 8.5-14.3	1.04 0.99-1.15
dicoccon	P.I. 56235	U.S.S.R.	16.3 13.3-18.5	1.20 1.07-1.37	15.9 13.9-17.9	1.18 1.02-1.26
dicoccon	P.I. 221398	Yugoslavia	9.5 6.8-11.5	1.17 1.07-1.30	8.6 5.7-11.8	1.20 1.05-1.30
dicoccon	P.I. 221403	Yugoslavia	12.5 10.4-14.9	1.31 1.20-1.42	12.8 11.9-14.6	1.35 1.30-1.40
dicoccon	A. 11119	Yugoslavia	12.1 8.6-14.6	0.99 0.90-1.11	10.8 8.7-13.4	1.03 0.97-1.12
dicoccon accessions total			12.8 6.8-18.5	1.12 0.90-1.42	12.0 5.7-17.	1.14 0.97-1.40
turgidum[2]	--	unknown	10.0 9.8-10.2	0.82 0.80-0.88	9.2 7.2-10.2	0.79 0.72-0.82
carthlicum	P.I. 78812	Iran	8.2 6.1-10.9	1.18 1.10-1.30	6.2 3.6-8.1	1.14 1.10-1.20

VITA

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Doctor of Philosophy

Thesis: CYTOGENETICAL AND MORPHOLOGICAL STUDY OF ISRAELI AND TURKISH WILD EMMER (TRITICUM TURGIDUM L. EM. VAR. DICOCCOIDES /KÖRN/ BOWDEN) COLLECTIONS AND THEIR RELATION TO OTHER TETRAPLOID WHEATS

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